WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

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TRANSMISSION *at*

OWEN FALLS

The many miles of power, distribution and control cables required for the first four generators at Owen Falls have been supplied and installed by the BICC Group.

First 132 kV Overhead Line in East Africa

One hundred and twenty route miles of 132 kV overhead line are being erected by the same organization to carry power to Tororo and Kampala — the first 132 kV overhead transmission line in East Africa.

This contract for the Uganda Electricity Board is typical of the work carried out by the BICC Group in power transmission and distribution, in many parts of the World.

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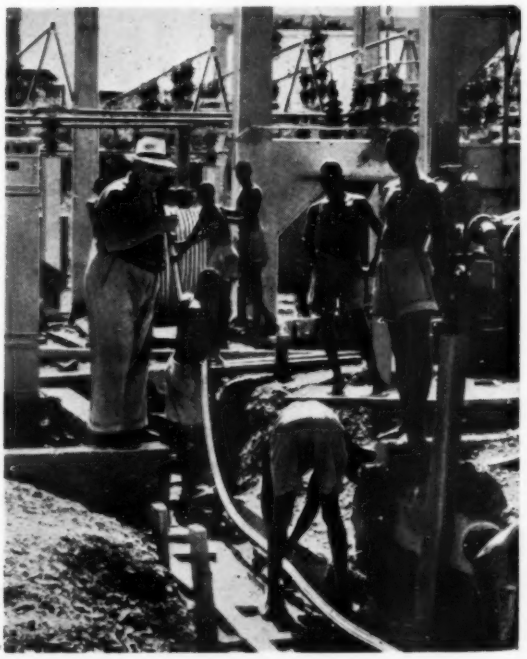

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WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

Sharing European Power

AN important stage was reached during April of this year in regard to the long-discussed cross-Channel power interchange scheme, whereby a 132 kV cable, some 24 miles in length, would be laid across the Channel to interconnect the French and British electricity-supply networks. A paper was presented to the Institution of Electrical Engineers in London by Messrs. D. P. Sayers, B.Sc., M.I.E.E., and F. J. Lane, O.B.E., M.Sc., M.I.E.E. (of the British Electricity Authority) and Monsieur M. E. Laborde, Ing.E.S.E., L es Sc., of Electricité de France. It surveyed the results of extensive tests carried out since 1950, when a Joint Technical Committee, representative of the two national electricity authorities, was set up to consider this problem.

The Committee issued an interim report in 1952, in which it was stated that from a purely theoretical basis there seemed to be no obstacle to the scheme, but the suggestion was also made that it was necessary to carry out major practical tests on the laying and jointing of the cable. For this purpose three lengths of cable, two of British origin and one made in France, with a total length of some 2,000 yards and including four joints, was laid out from the coast near Dover into the Channel during the summer of 1953.

The paper presented by Messrs. Sayers, Laborde and Lane was an extremely comprehensive document in which the practical problems of cable design, manufacture and laying were shown largely to have been solved; also the operational possibilities of such an international power link were demonstrated to yield economic benefits which would clearly justify the inception of the project. It might be said that although it still remains for the engineers on both sides of the Channel to present a formal report to their Governments, this paper was in effect the presentation of such a report to the engineering world, and it remains only for the politicians to authorise the expenditure of the relatively modest sum of £4·3 million, shared between the two authorities, before the scheme could be inaugurated. It was thought that three to four years would be necessary before the necessary equipment could be manufactured, installed and brought into use.

The hydro-electric engineer will be especially interested in this project because of the large part played by hydro-electric energy in the economic foundations on which the plan for a cross-Channel link is based. Great Britain is self-sufficient as regards power, and at the present time, at any rate, there is no question of having to install a link with the Continent because of absence of natural resources. The onset of atomic power will not alter the picture materially; in any case it is inconceivable and, indeed, has never been suggested, that the vast reserves of hydro-electric energy—both those at present harnessed and those about to be exploited—should be abandoned in favour of the total generation of power by means of controlled nuclear fission. The capital costs of atomic power stations are bound to be high, and the cost per unit generated will be correspondingly elevated; but the very nature of the process means that a few large remote atomic power stations will be established, needing considerable numbers of highly skilled personnel. Atomic stations are not likely, therefore, to supplant water-power installations, but only to save irreplaceable solid fuel.

Thus the Channel cable project can be considered as a long-term scheme to extend the well-known benefits of economic interconnection between two large adjacent networks, in one of which hydro power plays a predominant part, and to exploit, in particular, the all-important diversity of demand, which can only be fully realised when the largest possible number of consumers are brought into connection with a common network.

The British system, at the end of 1953, comprised 16,984 MW of thermal plant and 172 MW of water-power stations, while the network of France included at the same period 7,197 MW of thermal generation allied to 6,612 MW of hydro-electric plant. The annual load factors on the two networks differ con-

siderably. Whereas, in Great Britain only 44·9 per cent. load factor can be achieved, in France the much higher figure of 61 per cent. was registered last year.

The diversity of total demands in Britain and in France during the cold spell in the early part of this year reached a figure of about 580 MW, as was pointed out by a member of the British Electricity Authority's operation staff during the discussion. In the paper the authors showed that the French peak usually occurred about one hour before the British peak, while the biggest demand risk occurs on Wednesday in France and on Monday in Britain. The authors stated that a minimum winter diversity of 300 MW could be relied on, and thus with a 100 MW cable—the size indicated for the initial connection—each country could rely on receiving at the time of its maximum demand 100 MW from the other country, thus making possible a reduction in the generating-plant capacity which would otherwise have been necessary in each country. Thus a capital saving of about £5,700,000 could be envisaged.

Three types of energy exchange are likely to take place, once the link is complete. First, there is utilisation of spill energy from the French hydro-electric stations. This energy, which would otherwise be wasted, could be absorbed in Great Britain. Secondly, there is the possibility of "barter" exchanges, hydro-electrical energy being transmitted from France when the reservoirs are full and when British thermal plant is fully engaged, and repaid by thermal energy from Britain to meet the convenience of French consumers. By these means the French hydro-electric schemes could be more closely controlled, and the joint economy of both systems substantially improved. Finally, there are the possibilities of thermal-thermal power exchanges, based entirely on costs of production in steam stations at given periods and load levels.

The scheme will make engineering history, as it will involve one of the longest and most difficult cable connections yet planned anywhere. It is based, of course, on the hydro-electric possibilities rather than on thermal-thermal plant energy exchanges which, in themselves, would not provide adequate financial justification.

Already there exist the rudiments of a Western European grid. With the weight of Britain's large and growing thermal installations joined to the vast Continental hydro-electric resources still to be developed, the best possible use will be made of every form of natural resource needed for power generation.

Turkish Contracts for Britain

AN agreement has been signed by the Turkish Government with two British firms for the construction of a dam and power plant at Hirfanli on the Kizilirmak river, about 65 miles south-east of Ankara. George Wimpey & Co. Ltd have obtained the contract for the civil-engineering work, which comprises a dam 280 ft. high and an adjacent power station, and the mechanical and electrical plant will be supplied by The English Electric Co. Ltd. The capacity of the station will be 100 MW and the cost nearly £90 million Turkish, equivalent to nearly £12 million sterling. About £6 million will be payable in sterling, and 40 per cent. of the sterling payment is to be paid within four years. Credit, backed by the British Treasury, has been granted to the Turkish Government for nine years at 5 per cent.

Owen Falls Official Opening

ON April 29, almost immediately after this issue is due to appear, the Owen Falls power station is to be opened by Her Majesty The Queen. Although there are many larger schemes in existence, both in the British Commonwealth and in other countries, the ceremony is significant in that it sets the seal on an enterprise that is uniquely British in its conception and execution. Two eminent firms of British consulting engineers have been retained, and the plant has been supplied by British contractors whose names are household words in hydro-electric engineering. Although we stress the part played by British contractors, we have no wish to minimise the important participation of the four Dutch contracting firms who were so happily associated with the scheme in connection with the large amount of civil-engineering work involved. In a matter of this kind substantial advantages are gained by drawing trained personnel from as large a field as possible at a time when there is such a heavy demand on specialised services.

The scheme will bring incalculable benefits to a remote and sparsely inhabited country, which has hitherto made very creditable progress with a minimum of mechanical power, as there are no known indigenous supplies of fuel, which have necessarily to be imported over a haul of over 700 miles.

Papers on the development are to be read towards the end of May before the Institution of Civil Engineers, and a further paper before the Institution of Electrical Engineers, and we understand that Mr. C. R. Westlake, M.I.E.E., chairman of the Uganda Electricity Board, by whose initiative this scheme has materialised, will be there in person. A full account of the scheme will appear in the June and July issues of this journal.

Snowy Mountains Estimates

ACCORDING to a recent announcement by Senator Spooner, the Snowy Mountains project is now expected to cost £422 million compared with the previous estimate made in 1952 of £442·5 million. Of the £422 million new estimate, £374 million represents the cost of power generation up to and including central collecting points in the area, and the remainder covers the cost of the transmission system from the collecting points to the load centres. Although this total represents a heavy increase on the original estimate of £245 million in 1948, when basic costs, of course, were much lower, this announcement effectively disposes of rumours current last year that the total cost would be between £600 million and £700 million.

Doubts have also been expressed by the State Electricity Commission of New South Wales whether power could be supplied from the Snowy Mountains development to fit in with their technical requirements, but it is stated that the Authority can now guarantee under all conditions 50 per cent. more power than it could under earlier plans.

It is anticipated that the Upper Tumut project, for which tenders have recently been called, will provide 80 MW of power by 1958 and 320 MW by the end

of 1959. In addition to this, 300 million acre feet of water per annum should become available in 1959 to the Murray River Irrigation Area, and over the next two years this quantity should be increased to 500 million acre feet per annum.

Kitimat-Kemano Development

LAST month Mr. F. L. Lawton of Aluminium Laboratories Limited of Canada presented a paper to The Institution of Electrical Engineers in which he described the electric aspects of the Nechako-Kemano-Kitimat development. As our readers will be aware from the two articles we have published in the March and April issues, the ultimate installed capacity of this gigantic scheme will be nearly 2¼ million horsepower and Mr. Lawton's object was to give particulars of the unusually heavy loading of the 300 kV transmission line, together with an analysis of the mechanical loading. Interesting leading particulars were given of the characteristics of the four-nozzle impulse turbines, the generators, the transformer banks at each end of the line, the switchgear, cables, auxiliary power supply, relay protection, metering and control, and of the communicating facilities which have been introduced.

Prestressed Dam

AN Algerian project involving the construction of a prestressed dam with a crest length of 1,600 ft. and a maximum height of 260 ft. has now been started on the Djen-Djen river. The dam will take the form of a series of arches, each with a double curvature, which will be supported at the abutments by buttresses 10 ft. thick and spaced at intervals of 116 ft. Thickness will range from 4½ ft. at the top to 8 ft. at the base and prestressing is to be applied by cables which will be put under tension by hydraulic jacks.

Scottish Hydro-Electric Contract

THE North of Scotland Hydro-Electric Board has awarded the contract for the St. Fillans section of their Breadalbane, Perthshire, scheme to the Mitchell Construction Company of Peterborough. It is understood that the value of the contract amounts to £4 million and that the work will be started immediately and will occupy 500 men for a period of about four years. The scheme provides for two generating stations, both of which will be underground, and the driving of some 17 miles of tunnelling. Three rivers are involved — the Earn, the Lednock and the Almond. It will be recalled that the Mitchell Construction Company is also engaged on the Board's Glenmoriston scheme (WATER POWER, December 1953, page 446) in which the Trief process of using ground blast-furnace slag to replace a certain proportion of the cement was used for the first time in this country in a civil-engineering work of this kind.

The longest tunnel will carry water from the reservoir in Glen Lednock to the power station in St. Fillans. It will be over 18,000 ft. long and will have a diameter of 9 ft. 6 in. Another tunnel 17,200 ft. in length and 10 ft. in diameter will bring water from Glen Almond to the reservoir in Glen Lednock. The third main tunnel, which will be 16,200 ft. long with a diameter of 11 ft. 6 in., will lead water from the outlet of Loch Earn to the power station at Dalchonzie.

Taylor Woodrow Construction Limited have been awarded the contract for the construction of the Lednock dam which will create a new loch near the head of Glen Lednock. This buttress-type dam will be about 930 ft. long and 100 ft. high and its construction will involve the placing of over 100,000 cu. yards of concrete.

In preparation for the construction of the works in Glen Lednock, the road up the glen had to be rebuilt. It was completed ahead of schedule by Messrs. Struthers and Denny of Edinburgh.

Vancouver Island Power Extension

APPROVAL has at last been obtained to proceed with the construction of a storage dam at Buttle Lake on Vancouver Island. This will be of the earth and rockfill type and will greatly increase the amount of firm power derivable from the Campbell river, which is by far the most important source of power which the island possesses. The John Hart plant, with which the new dam will be immediately associated, will be especially benefited. This work will be undertaken by the British Columbia Power Commission and is expected to be completed late in 1955.

Orders for Heavy Equipment

THE Organisation for European Economic Co-operation, which periodically undertakes a study of orders booked for heavy power-station equipment, has recently issued a report on this subject. Deliveries of hydro-electric equipment represent a slight improvement on those for the previous 15 months and it is expected that they will be stepped up during the next six months. Turbine exports have mainly been to non-member countries and to overseas territories, and orders booked since April 1953 are stated to be higher than deliveries during this period. Deliveries of alternators for hydro-electric plants—and units of 10,000 kW or over only are considered—are keeping well up to orders, but on the whole new orders, though still on the increase, are not quite sufficient to keep pace with the delivery potential. Out of 10,427 MW of orders booked for delivery before the end of March 1957, 2,000 MW have been delivered. New orders for delivery up to this date total 9,621 MW so that they represent only 1,374 MW as against deliveries of 2,000 MW.

Tothill Press Limited

Mr. George Rollason, Deputy Chairman and Managing Director of Tothill Press Limited, the company which owns and publishes this journal, and with which he has been associated for over 40 years, is, at his own request, relinquishing the office of Managing Director. He will remain on the Board as Deputy Chairman, and his long experience in publishing will continue to be at the disposal of the Company.

Mr. B. W. C. Cooke and Mr. R. H. Gosling have been appointed Joint Managing Directors. Both have been associated with the Company for many years, Mr. Cooke as Editorial Director and Mr. Gosling as Director and Secretary.

Fig. 1. Bhakra gorge looking upstream, showing part of the Bhakra-Nangal highway

India's Bhakra-Nangal Project

An Indian correspondent describes a major scheme on the Sutlej river in the Punjab which will provide 400MW of firm power and irrigate six million acres.

PART ONE

IT was a British civilian who, as far back as 1908, dreamt of a dam in the Sutlej gorge where the 680 ft. high concrete gravity Bhakra dam is now being built. He was Sir Louis Dane, the then Lieut.-Governor of the Punjab. Thereafter the site was examined by many geological and engineering experts in order to verify the suitability and soundness of the construction of a high dam to store the surplus waters of the Sutlej river. Originally, a dam 400 ft. high was proposed without any provision for the generation of power. The project was revised in 1939 and 1942, increasing the proposed height of the dam to 500 ft. In 1948, the final proposal of raising the height of the dam to 680 ft. was accepted in view of the greatly increased irrigation and power benefits.

Despite the many doubts expressed by many political leaders and experienced economists about the wisdom of embarking on an Rs. 1,500 million (£113 million approximately) multi-purpose project right at the beginning of India's post-independence development programmes, funds for this project are being sanctioned by the Government of India at top-priority considerations. It is to be noted that £113 million is more than one-third of the Government of India's annual budget.

Activity is now increasing on the project sites in order to achieve the target of completing the first stage of the project by the middle of 1954. This stage comprises the commissioning of the Gangowal power house on the Nangal Hydel channel with its installa-

tion of two units of 24,000 kW capacity.

Principal Features of the Project

As now framed, the Bhakra dam project will generate 400 MW through its Left-Bank and Right-Bank power plants. The Left power plant will have an ultimate installation of six units of 90 MW each coupled to runners of 125,000 h.p. In addition, the Nangal dam will provide, ultimately, 164 MW from its three power plants on the Nangal Hydel channel.

Being a multi-purpose scheme, the Bhakra Nangal also aims at providing irrigation to about six million acres of land, in addition to its power benefits. At present, these lands are either unirrigated or insufficiently irrigated and are thus the scenes of recurring famines. The people of these arid areas have been suffering food and fodder shortage in years of drought with consequent loss to animal and human life on a disastrous scale. With the introduction of flow irrigation, the inhabitants of this area have in prospect the long-awaited prosperity which has invariably followed the introduction of canal irrigation ever since the early days of British domination of India.

The essential feature of the project is the construction of a monolithic concrete dam, 680 ft. high, at the site of the Bhakra gorge. The dam will pond up the waters of the Sutlej above this point to the tune of 7·38 million acre feet per year, of which nearly 5·7 million acre feet will be available for hydro-electric power generation and irrigation purposes.

According to the latest design, the reservoir level of the dam has been kept at 1,680 ft. above sea level. The stored waters will be capable of providing irrigation facilities to lands in Punjab, Pepsu and Rajasthan.

The scheme also provides for an auxiliary dam across the Sutlej at Nangal, about eight miles downstream of Bhakra. This will divert the river into the Nangal Hydel canal, and at the same time serve as a balancing reservoir for daily fluctuations of supply from the Bhakra dam, and for meeting the daily and weekly load variations on power stations on the Nangal Hydel canal.

The main structure of this auxiliary dam has been completed, and some time in the middle of 1954 water will run into the Nangal Hydel canal for production of hydro-electric power at Gangowal power station and irrigation in the Punjab State. The Nangal Hydel canal has a capacity of 12,500 cusecs and its entire length of 39·6 miles will be lined. The Bhakra main canal is to take off from the tail of Nangal canal near Rupar (see Fig. 2), and it is to be 108 miles long with a network of branches, distributaries and minor canals.

The total length of main canals and branches in the Bhakra canals system is about 540 miles and that of distributaries and minors about 2,400 miles.

Bhakra Dam and Diversion Tunnels

The dam is located in a narrow canyon, about 400 ft. wide at river level at an elevation of 1,200 ft. above sea level, with steep faces of the canyon walls which rise to a height of approximately 2,500 ft. on either side. The canyon cuts into members of the lower Siwalik formation, the basalt beds of which are preponderantly sandstones, but with important claystone-siltstone layers intervening between hard

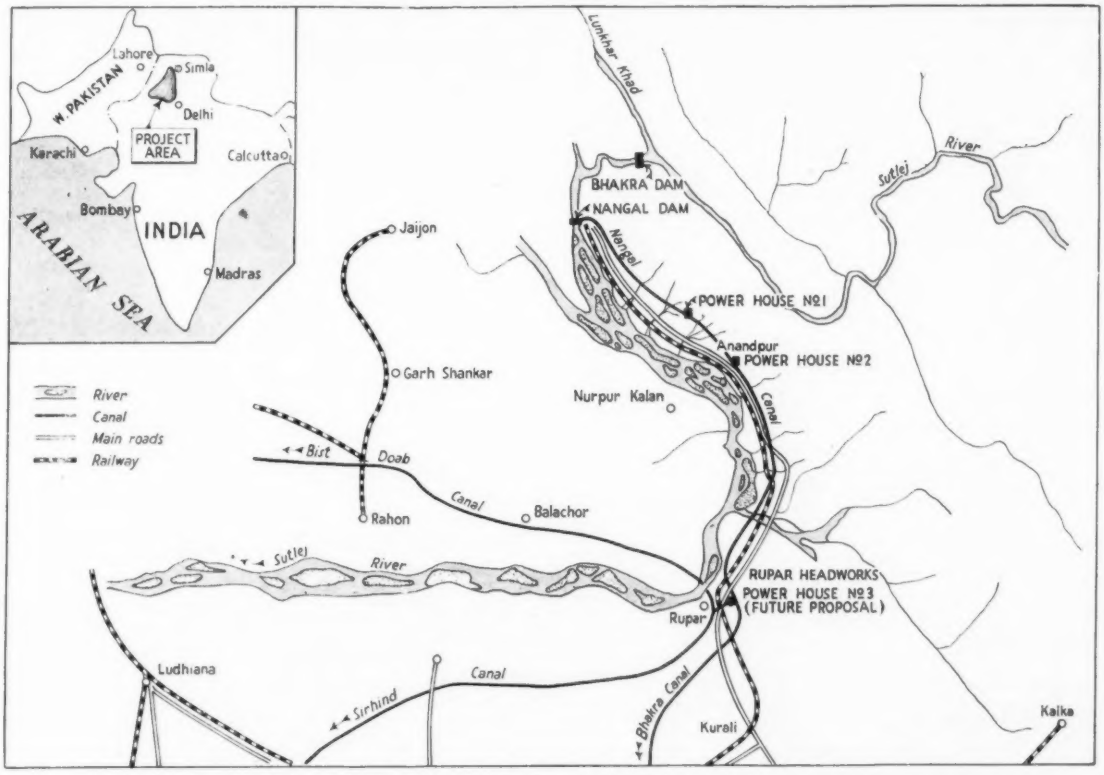


Fig. 2. Map of India and the Punjab showing the location of the Bhakra-Nangal project

sandstone horizons. In addition, there are occasional shear and thrust zones (zones of broken or shattered rock) in an otherwise sound and massive sandstone rock.

The stratification is about at right angles to the gorge. At higher elevations, however, there is some deviation in this attitude of the beds due to slight cross-folding. The beds are tilted at angles between 70° and 75° in the downstream direction at lower levels, but this is not uniform and there is a flattening of inclination of beds at higher levels on the abutments.

Information about the thickness of overburden and of excavation necessary before suitable bedrock is reached has been secured through exploratory programmes planned over a period of seven years. To date, the explorations cover a total of 98 drill holes, aggregating 16,368 ft. in length. In addition, 67 tunnels or exploratory drifts, many with crosscuts, have been excavated to a total length of 3,934 ft. The exploration of the foundations is being carried out in co-operation with the Geological Survey of India who were assisted for a few months in 1946 by the American engineering geologist, Dr. F. A. Nickell.

Results of exploration indicate that excavation of unsound rock in the vicinity of the dam will be over 4 million cubic yards in volume. The depth of excavation is expected to increase steadily from 15—20 ft. near river level to depths of 60—70 ft. on the right side and 150 ft. or more towards the upper limit of the left abutment. The depth of sand, gravel, boulders and other muck requiring removal within the river section, will vary from 50 to 140 ft.

In addition to general excavation, special zones such as shear zones and bands of softer rock like claystone-siltstone bands persisting below the average of the excavated surface are to be given special treatment by selective excavation, careful backfilling with concrete, and selective grouting.

General pressure grouting will also be carried out over critical and relevant sections of the dam foundations in order to seal all joints and fissures effectively.

The dam will be of the straight gravity concrete type. With the present designed reservoir level of 1,680, it will have an overall height of 680 ft. and a length of 1,600 ft. at the top. The total width of foundations in its central or spillway section will be about 1,100 ft., while that of the abutment sections on either side will be 600 ft. The roadway at the top will be 30 ft. wide.

The upstream face of the dam is vertical down to elevation 1,350, with a batter of 0·35 to 1 below that level. The downstream face has a batter of 0·8 to 1 down to about the natural bed of the river, extending into a stilling apron with a slope of 30 : 1 in the spillway section.

An overflow spillway, 260 ft. long, fitted with four 50 ft. by 37 ft. radial gates, will be provided in the central section of the dam. The spillway apron will be divided into two compartments by providing a central partition wall, 5 ft. thick at the top and 15 ft. thick at the bottom. The discharge intensity in a maximum flood discharge will be 1,160 cusecs per foot run.

Originally it was also intended to provide another spillway in one of the diversion tunnels. This inclined tunnel spillway with its crest level at elevation 1,630 had a capacity of 153,300 cusecs. It has now been eliminated, and the overflow spillway in the dam widened from its original width of 220 ft. to 260 ft. to accommodate the routed flood discharge of 290,000 cusecs in conjunction with the river outlets. This elimination will save nearly Rs. 6,000,000 (nearly £450,000).

Provision was also made in the original design for a number of outlets in the right diversion tunnel. The only function of the tunnel outlet works, after construction was completed, was to pass the irrigation supply when the spillway apron was under repair. Because of the central wall in the spillway apron, it will now be possible to close one compartment of the spillway for repair in case of damage and run the irrigation supply in the other half, so that these outlet works have also been eliminated. This will save about Rs. 6,500,000 (£687,500) and materially expedite the completion of the right diversion tunnel, thus easing a very tight construction schedule.

As a result of the elimination of the tunnel outlet works, the original design of 24 outlets with 96 in. diameter jet dispersers in three tiers of eight each, has been changed to 20 river outlets with 96 in. jet dispersers in two tiers of ten each at elevations 1,320 and 1,420.

These river outlets will be capable of passing a discharge of 106,000 cusecs. The spillway and outlets will be able to deal with an unrouted flood discharge of 400,000 cusecs. However, taking advantage of the available storage between maximum reservoir at elevation 1,685 and normal reservoir at elevation 1,680 for the absorption of the peak will give a routed flood outflow of 290,000 cusecs only.

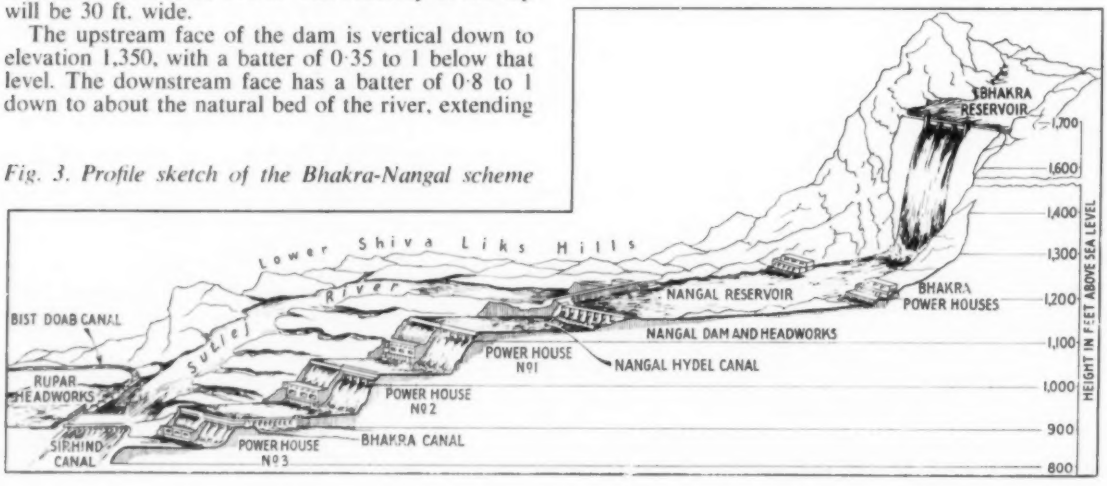


Fig. 3. Profile sketch of the Bhakra-Nangal scheme

Fig. 4. Exploratory drilling on the left bank

For the excavation of foundations and construction of the lower portion of the dam, the river is being diverted through two 50 ft. diameter diversion tunnels, concrete lined, each about half a mile long, one on each side of the dam. The tunnels, which are now nearing completion, were excavated to a diameter of nearly 60 ft. and concrete lined so as to give an internal diameter of 50 ft.

Model experiments were carried out to find the coefficient of discharge that could be adopted for checking the height of the cofferdam. So as to lessen the entrance loss and heavy contraction which was seen in the experiments, smooth approaches were designed for the portals.

Preliminary geological survey showed that the tunnels would have to pass through strata ranging from jointed sandstone to indurated clay. These investigations indicated that the construction of the diversion tunnels would be best accomplished by the pilot-heading method, and pilot headings, 10 ft. square, were excavated from both ends of each tunnel. Timber and heavy steel supports were required in the various stages of enlargement. At the moment of writing, the excavation of the tunnels is complete and the lining was expected to be finished by November 1953, when the river would be diverted into the tunnels. The concreting operations have been mechanised to a very great extent, and steel gantries and concrete pumps used for the work.

The number of shot holes drilled in the pilot headings varied from 20 to 26, depending upon the nature of the rock. The holes were drilled by means of Ingersoll Rand jack hammers, and the explosive used was gelignite. The muck was removed by means of 1 cu. yard capacity push tip wagons operated by manual labour.

The total amount of excavation required on one tunnel was nearly 258,000 cu. yards, and the overall cost of excavation per cubic yard was Rs. 40/8 (£3).

Steel shuttering for concreting the arches of the diversion tunnels was designed to take a load of 7 ft. of concrete. It was of local manufacture. The procedure in concreting the tunnels consists of laying

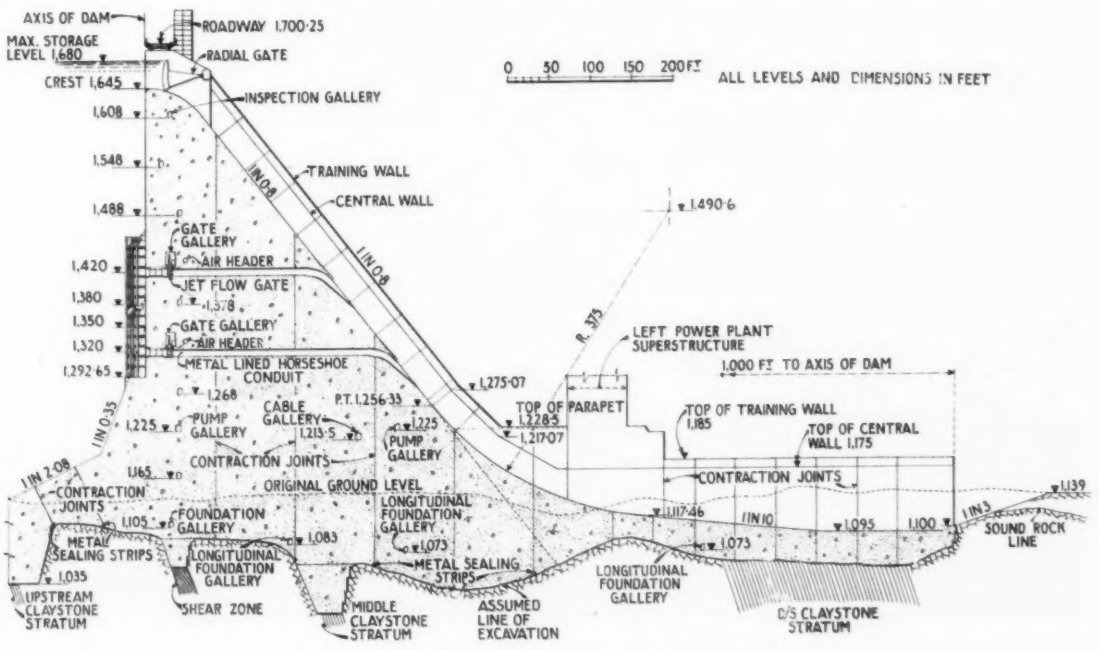


Fig. 5. Cross section through the Bhakra dam

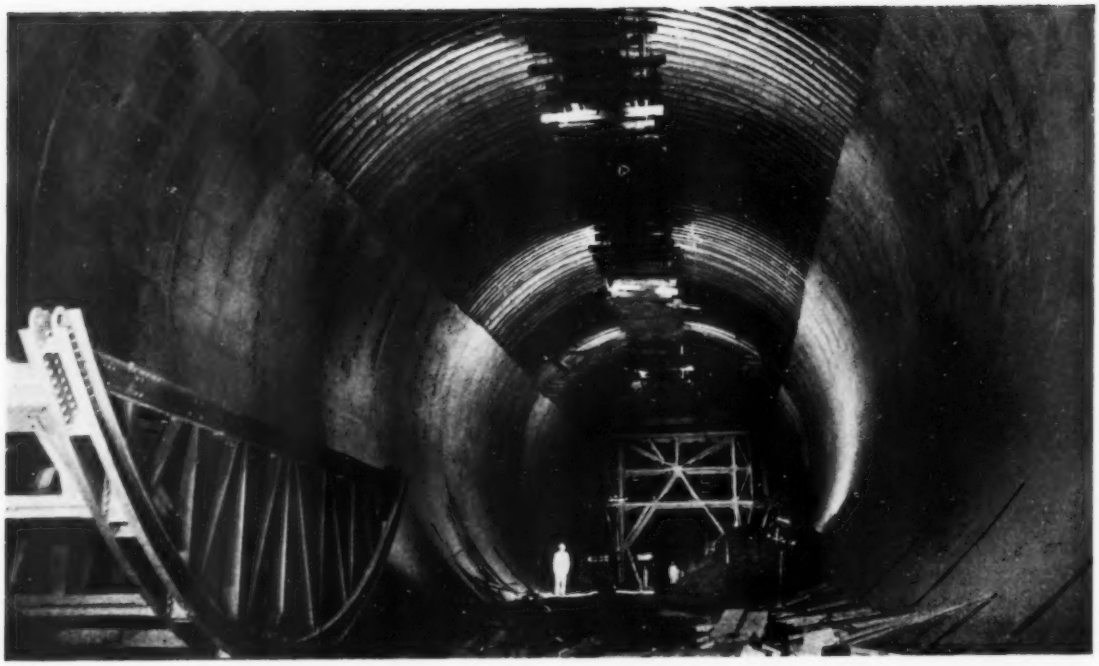


Fig. 6. Inside the right diversion tunnel showing concrete lining completed to the top of the walls

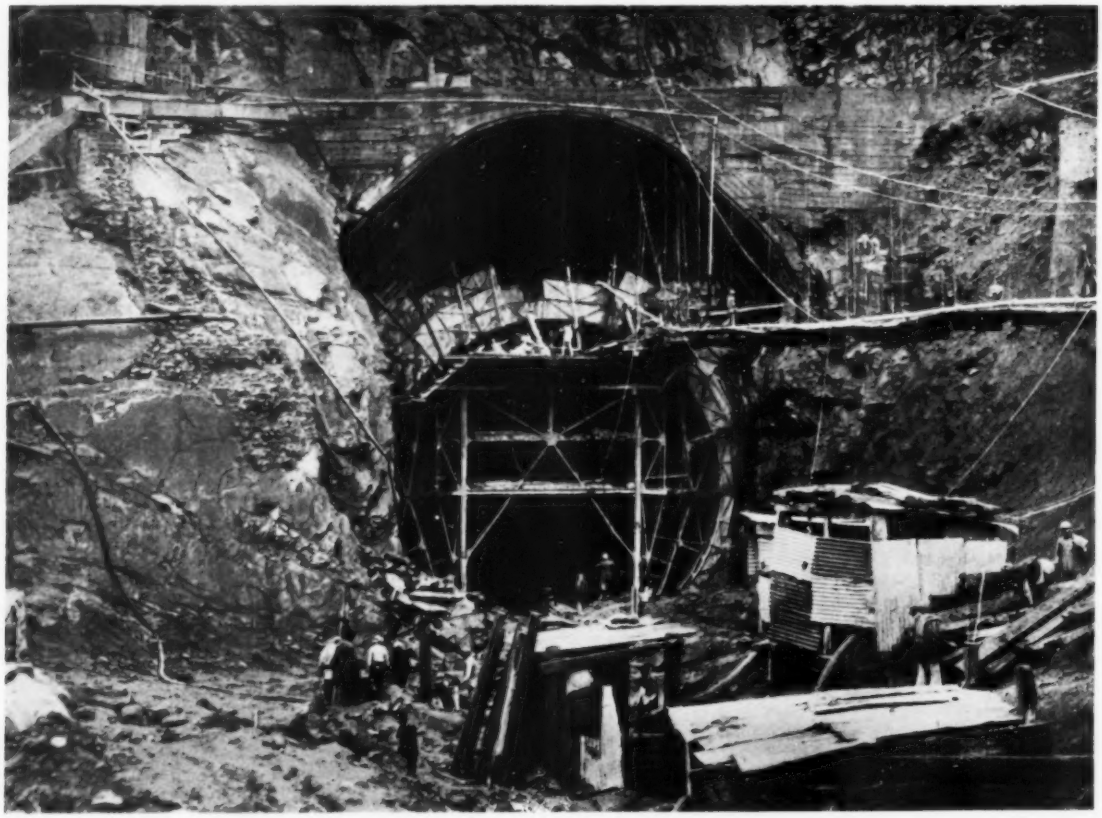


Fig. 7. Downstream portal of the left diversion tunnel. The end will be circular instead of elliptical as first contemplated

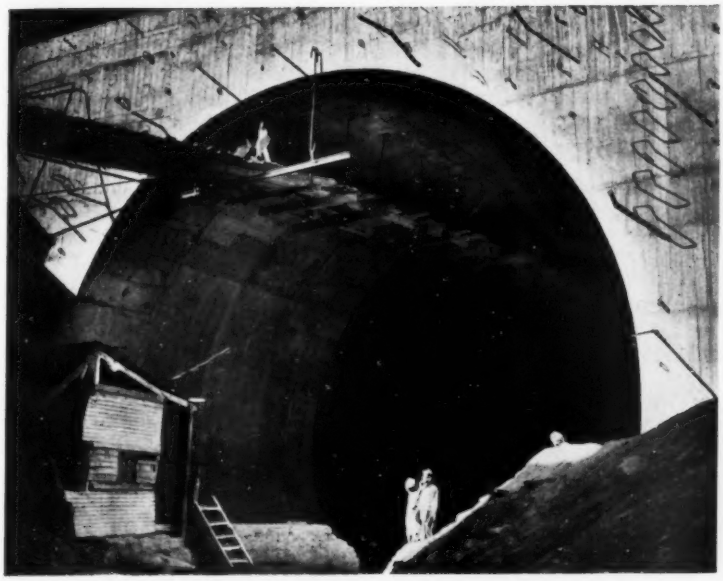


Fig. 8. Upstream portal of the right diversion tunnel

74° invert first, then 88° side walls and last the 110° arch roof.

Both low-pressure and high-pressure grouting processes are used. In the case of low-pressure grouting, grout is injected at a pressure of about 30 lb. per sq. in. into the voids between the arch sections of the linings and the rock, 1½ in. pipes being generally used for this operation. In addition to the grout pipes, vent pipes are sometimes provided for the release of air and water during the grouting operations when the overbreak exceeds the average.

For high-pressure grouting, grout holes were drilled at two suitable locations approximately radially through the concrete lining. At the first location the sections drilled and grouted were at the diversion tunnel plugs, and the direction of the holes was such as to make contact with the high-pressure grout curtain established

Fig. 9. Upstream portal of the left diversion tunnel at an early stage of construction, viewed from inside the tunnel

at the other location. The conditions encountered during the actual work helped in determining the number, direction and length of holes, time of grouting, consistency of the grout and pressure to be used.

The high-pressure grout holes in the tailrace tunnels were drilled approximately normal to the concrete lining.

Cofferdams

The 1947 flood of 275,000 cusecs determined the crest of the cofferdam to be at elevation 1,280. This has been chosen because, when routed, the 1947 flood had an elevation of 1,271, and 9 ft. of freeboard is allowed for the crest.

The proposed section of the dam just fits in between the upstream tunnel portals and the outcrop of a claystone stratum, and provides a working berm at the toe, clear of the claystone. The exact location of the claystone is still under investigation, and if it encroaches upon the cofferdam, the cofferdam will be steepened and locally curved to provide the necessary berm, or, on the other hand, the berm width may be decreased.

Seepage through the cofferdam is expected, but this will be controlled by a concrete gravity wall at the downstream toe. Pipes will be embedded in this wall and connected to headers for pumping off the seepage water.

In view of the possibility of a spill over the cofferdam, it is also planned to protect the downstream face by means of a 12 in. thick concrete slab with transverse and horizontal reinforcement. The spacing of the reinforcement is such as not to permit rolling movement of the rock pieces. The mesh will be held in position by anchor blocks embedded 10 ft. deep into the cofferdam.

The dam is expected to be complete by 1959, but irrigation will be initiated in 1956, when the height of the dam will permit a storage up to elevation 1,330. Water, therefore, will be diverted through the two diversion tunnels until November 1955, when the right tunnel will be closed by upstream and downstream cofferdams. A portion of the tunnel plug containing two conduits and regulating gates will be placed by April 1956, while the river water will continue to pass through the left diversion tunnel. In April 1956 the right tunnel conduit will be opened to assist in passing inflows of the monsoon season.

Storage for the year 1956 will be started by closing the left diversion tunnel by stoplogs in August or September 1956 and regulation of the discharge through the right tunnel conduit. Similar arrangements will be followed for storage of supplies for the years 1957 and 1958, except that the reservoir will be filled to higher levels and regulation assisted through the river outlets as well. In the year 1958, when the reservoir level rises to elevation 1,340, the right tunnel conduit will be closed and the remainder of the plugs placed to seal the tunnels finally, as they will no longer be required to pass any of the river supplies.

(To be continued)

The Shawinigan Water and Power Company

The 56th annual report of The Shawinigan Water and Power Company shows that the revenue from sales of electricity totalled $38,800,816, an increase of 3·3 per cent. over 1952, and once again a new record. Revenue from primary power sales to industrial customers was down 1·5 per cent. to other utilities for resale up 10·2 per cent., and to residential, farm, commercial and municipal consumers up 12·2 per cent. Revenue from sale of secondary power was 5·1 per cent. lower than in 1952.

Other revenue from power operations was substantially higher, largely due to increased rentals received from others for the transmission of power over the Company's lines.

Dividends from subsidiary and other companies were 4·8 per cent. higher, principally as a result of the increase from $1 to $1·20 per share in the dividend paid by Quebec Power Company.

Operating expenses, other than depreciation, were 5·7 per cent. higher than in 1952. Another factor was the 9·3 per cent. larger expenditure for purchases of power from other generating companies, occasioned by the very dry weather during the summer and autumn.

After all charges and after providing for dividends on the Preferred Shares, net earnings from all sources available for dividends on the Common Shares totalled $2·26 per share as against $1·91 per share in 1952. The portion of these earnings derived from power operations was $1·46 compared to $1·15 in 1952, about half the improvement being due to a greater margin of revenue over expenditure, and half to lower income tax. Regular quarterly dividends totalling $1·20 per Common Share were paid during the year and, for the fourth consecutive year, a special dividend of 25 cents per share was paid at the year end, bringing the total dividends for the year to $1·45 per share.

Shawinigan Chemicals Limited, a wholly-owned subsidiary, had a substantially better year.

The President, Mr. J. A. Fuller, states in the report that to provide for further anticipated increases in demand, a decision as to new sources of power supply has been reached. These additional power supplies to the extent of 150,000 h.p. are to be assured by installation of a further generating unit in each of three generating stations at Rapide Blanc, Trenche, and at the La Tuque plant of St. Maurice Power Corporation, scheduled for production in 1955, and by the purchase of 300 MW from Hydro-Quebec's Bersimis River development for gradual delivery over the years 1956-1960. This power, together with the additions now being made to the Upper St. Maurice plants, will take care of the growing needs for some years to come.

Capital expenditure over the next four years for the additional generating units and for normal expansion will be about 50 million dollars, which it is expected will be met to a large extent from present funds and from amounts available from the Company's operations.

The Moriston Dam Scheme. Mitchell Engineering Limited have issued an admirably produced brochure on this scheme, special attention being given to the Trief cement plant erected at Cluanie. The entire scheme, however, is fully described, the text being supplemented with maps, drawings and photographs.

Bolted Support for Tunnels

Professor Dr. Techn. L. v. RABCEWICZ, Stockholm,
describes the technique of roof bolting and recounts its advantages, particularly when driving through unstable rock.

PART TWO

Practical Details

Round mild steel is the best material for the bolts. The quality mostly used for this purpose in the States has 0·20 per cent. carbon content, a yield point of 2,400 kg. per sq. cm. and a tensile strength of 4,000 kg. per sq. cm. In Germany the steel quality 37 seems to be most suitable. The diameter should not be smaller than 20 mm. for short bolts, and 25 mm. for bolts longer than 1,500 mm. Bolts that are too thin cannot be driven properly and moreover are too much weakened by the slit. At the outer end the bolts are threaded for a length of 150 to 200 mm. Many different types for each of the anchoring systems shown in Fig. 4 have been developed, but in spite of its smaller anchoring effect the slit-and-wedge anchor is much more used in American mines due to its simple construction and low price. This is not so in Germany, where the sleeve expansion anchor is the most preferred, owing to the fact that rock conditions are generally much worse there than in the States. A further advantage of expansion bolts is that the holes need not be drilled to an exact length.

In Fig. 4 are shown different types of slit-and-wedge anchors, the most suitable form of which needs to be determined for each case separately[2]. The slit is preferably made by gas cutting as the rough surface gives a better hold for the wedge. The bolt transfers its tension to the rock by means of a plate or washer having dimensions of about 200 × 200 × 10 mm. Different types of plates have also been developed, such as square and triangular with flat or joggled surfaces. The latter should provide a better grip on the rock.

It very often happens that the rock surface is not perpendicular to the axis of the bolt, and in such cases either hardwood wedges or special angle washers, usually made of cut angle section, are used to obtain better contact between plate and rock. Different inclinations of the plate can be obtained by taking angles of uneven legs. In Germany a plate is used for this purpose, the middle part of which is joggled to a hemisphere with a slit instead of a round hole. This kind of plate gives close contact to the rock up to an angle of 45°.

In pretty bad rock it is expedient to connect the bolts with each other in order to distribute the load and to prevent relative movement, as well as to support the rock between the bolts. For this purpose steel channels of 120-150 mm. are most suitable. Also ties have been used in some cases. Experience has shown that as a rule it is easier to place them parallel to the tunnel axis as the surface of the tunnel is more even in this direction and practically the same static effect is obtained. Moreover, costly curving of the channels is avoided with longitudinal placing. In most cases the fixing of the channels is simplified by following the traces of the border shotholes.

The bolts, provided with wedge, plate and nut, are driven home by stope hammers fitted with a capped headpiece to protect the thread of the bolt. The holes in the channel bars are drilled beforehand. The drilling of holes in the rock, and the application of the bolts and channels proceeds gradually from a suitable point. On tightening the nuts the channels are bent, thus fitting roughly to the configuration of the rock.

In the Ruhr steel cables are preferred to the stiffer channels, special washers being inserted to carry them. Cables obviously follow the rock face more smoothly and are easier to fasten, as the bolts are not bound to fixed distances by holes drilled beforehand in the channels; also the lagging can more easily be placed over the cables than over channels. On the other hand, the rigidity of the channels gives rise to a considerably better load distribution.

If netting is required, wire meshwork—such as is commonly used for stone mattresses in river constructions—can be recommended. The net, which provides immediate protection for the workers, is best fixed temporarily by a number of short bolts, and not until this has been done should the drilling of the long holes be started (see Figs. 11 and 15)[7]. In this way the net is gripped between the channels and the rock. The nuts are usually tightened by means of a pneumatically driven wrench, as manufactured by a number of firms, e.g., Ingersoll Rand and Chicago Pneumatic Tool Company. Such a wrench is an indispensable tool for the roof-bolting technique, for the nuts are tightened very strongly within a few

Fig. 11. Roof bolting in the Forçacava pressure shaft

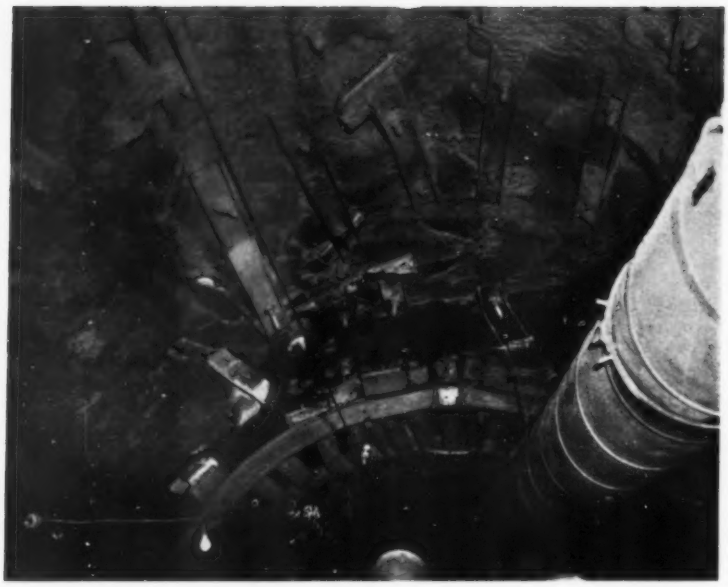


Fig. 12. New York water tunnel protected by roof bolting and gunite. Earlier steel-arch support can be seen in the background

seconds. The wrench can be adjusted to exert a predetermined torsional moment corresponding to the desired initial bolt tension and functions precisely provided that the thread is oiled.

The experience gathered with concrete anchors in soft rock is still insufficient for much more to be said about it. It seems anyhow that steel of smaller diameter can be used for reinforcement than is required for normal steel bolts. The diameter of the hole on the contrary should be greater, probably not less than 40 mm., in order to get a greater surface. Holes in the floor are first filled with mortar, then the bar is thrust in and the hole closed by a prefabricated concrete plug pressed into place. For horizontal and rising holes this system would not do, and an easy method would be to insert in the hole a corrugated steel bar with a small deaeration pipe attached to it, to fix at the entrance, which must be drilled sufficiently large, a short grout pipe and to grout the hole with a quick-hardening mortar (see Fig. 18).

Dry drilling has in any case proved to be considerably superior to wet drilling but especially in softer rock.

Historical Development and Recent Experience

The first attempts to replace old-fashioned timber supports by roof bolts can be traced back 40 years in European and American mines, but systematic research work on a larger scale was not started until 1948 by the U.S. Bureau of Mines. In a few years bolting has become so indispensable an element in the mining practice in the States that today several millions of bolts are placed monthly. The very deserving experiments with roof bolting of Mr. Z. S. Beyl, a Dutch engineer, carried out during the last war, must also be mentioned here[1]. His first trials go back to the year 1912. Mr. Beyl tried later to introduce the system into the English mines, but up to now it has not become as common in Europe as in America, undoubtedly partly due to an extremely cautious attitude on the part of the supervising authorities.

Tunnelling engineers were much more reluctant to adopt the method. In 1950 roof bolting was used for the 200 m. long Keyhole diversion tunnel in Wyoming and for a small part—only 60 m.—of the 9 km. long Duchèsne tunnel in Utah[3]. Later roof bolting was employed on a much larger scale by the New York City Board of Water Supply for its East Delaware tunnel during the years 1950-1952. This 60 km. long tunnel is still under construction. With the first two projects mentioned plates only were used, whereas for the New York water tunnel channels and ties were employed. The flat-bedded shales and sandstones in thin laminations of this tunnel were roof bolted for a length of 20 km., 124,000 bolts having been used (see Figs. 12 and 13).[5, 6] The most recent example of roof

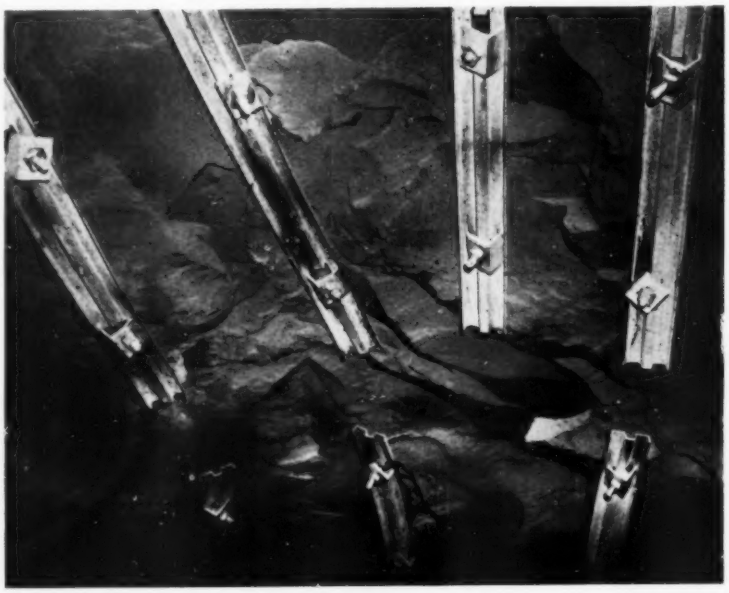


Fig. 13. Detail of roof bolting in the New York water tunnel before application of gunite

Fig. 14. Roof bolting in the Forçacava machine hall

bolting is that of the underground works at Kemano, British Columbia.[10]

In Europe there is a tendency to adopt this method in Sweden, but in most cases the object has not been to consolidate the roof by creating a natural arch capable of bearing but merely to protect the workers against minor falls of rock, sufficient security being obtained simply by fixing a net to the roof with anchor bolts. Roof bolting was also used in the Bowland water-supply tunnel in England.[1]

The author had the opportunity to make some tests with roof bolting in decomposed gneiss, with various degrees of chemical alteration, at the excavation of the Forçacava underground power plant in Brazil.[7] Based on accumulated experiences the method was used for the 420 m. long 42° inclined pressure shaft (sectional area 44 sq. m.) and the 24 m. wide excavated roof of the power house (see Figs. 14 and 15). For the worst part of the pressure shaft, where a large fault zone was crossed by a second joint system, 3 m. long anchor bolts 1 in. in diameter were used, connected by 6 m. long 120 mm. channels and completed with a wire net. The ground was successfully strengthened and secured in this simple and cheap way, but to have supported it by steel arches would not only have been very difficult and dangerous, having regard to the inclination of the tunnel, but also have meant a considerable loss of time and money.

Roof bolting in this case was carried out in the following manner. After blasting the round and roughly scaling the section, a heavy steel jumbo was brought forward and the most dangerous portions of the rock were supported by jacks and braced against the jumbo framework. The net was then fixed by a few short bolts, immediately followed by the drilling and the placing of the long bolts and channels. In this case the method was specially advantageous because it did not reduce the cross-sectional area, which made the erection of the heavy steel lining and concreting much easier.

A section of the roof of the power house was also roof bolted but unfortunately not until many weeks after excavation, and the nuts were only tightened by hand. When blasting close to the bolted area the layer supported by the bolts disintegrated. The drilling of the holes had obviously initiated very fine cracks in the strata which were at first invisible but caused later disintegration when vibrations were set up by blasting. However, in this instance, the bolting was applied too late and too incorrectly to be effective (see Fig. 16).

Today roof bolting is in process of official acceptance by tunnelling engineers not only in the United States but also in other countries, and has been adopted in the specifications of important tunnelling operations such as Australia's Snowy Mountains hydro-electric scheme and for the water-supply tunnels for Athens.

Advantages

The principal advantage of roof bolting is that a tunnel in bad rock can be driven full face, simply and quickly, without using supports that obstruct the workings. Full advantage can thus be taken of modern methods of mechanisation.

Another important advantage is that no wood is used as constructional material. Considered from this standpoint, not even the steel-arch method is as attractive as it seems at first sight, for the workers usually blast out considerable overbreak in order to avoid secondary blasting when setting the arches. The space between steel and rock is then filled with wood lagging and packing, unless steel lagging is used with gravel

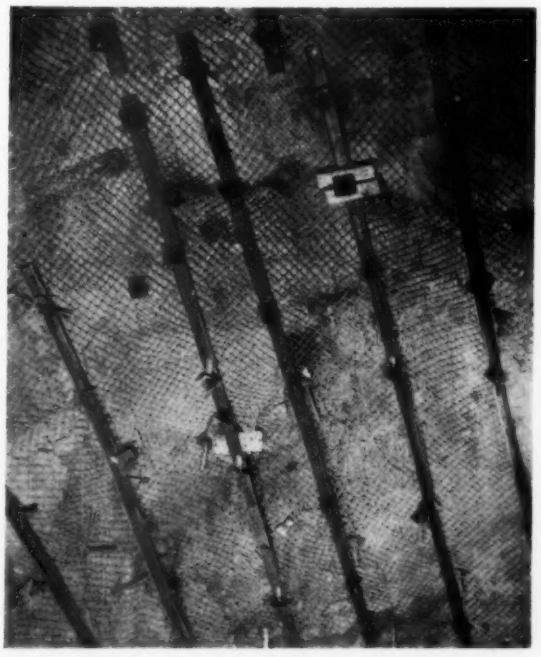


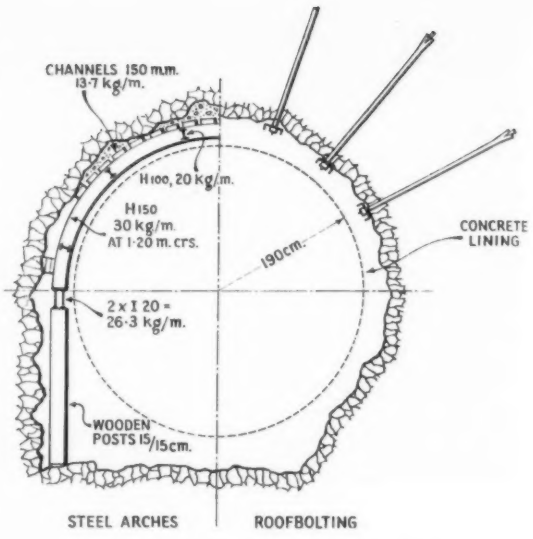
Fig. 15. Detail of roof bolting in the Forçacava pressure shaft showing wire netting fixed with short bolts before the roof bolts and channels are applied

blown in behind, the latter being of course an irreproachable method but an expensive one and not often practised. If wooden lagging and packing are used, the timber will be locked up behind the concreted arch and form a separating layer of a rather undesirable material between the rock and the concrete. Wood is bound to decay unless the tunnel is constantly under water, and will cause voids, irregular settling and eventually damage to the concrete lining.

There is no need to compare roof bolting with wooden multiple-piece sets as formerly used in the United States, because the use of wood instead of steel has hardly proved to be cheaper and is technically much inferior. The wooden frame has to be placed on the outside of the theoretical concrete line and this means a big overbreak volume to be filled up with concrete later.

Properly executed roof bolting will inhibit loosening better than any other method, as movements are either completely impeded or stopped immediately they commence. All temporary methods depending on support from below are bound to give way in course of time, and are naturally followed by a deepening of the loosening process. On the contrary, yielding with roof bolting amounts only to a fraction of the deformation the roof suffers with support from below.

A further advantage is that roof bolting is not damaged by fly rock from blasting, whereas other kinds of supporting structures will compel the workers to blast more carefully, which in turn results in a lower daily drivage rate. Finally, roof bolting causes less overbreak as no space need be left for any frames and lagging.



AVERAGE CONSUMPTION AND COSTS PER METRE RUN
(ESTIMATED FOR SWEDISH CONDITIONS)

Item		Sw. Kr.	Steel arches		Roof bolting		Saving	
			quantity	cost	quantity	cost	quantity	cost
Steel	kg	1	520	520	75	75	445	445
Wood	m^3	250	0·1	25	—	—	0·1	25
Working hours	h	10	137	1370	108	1080	29	290
Excavation	m^3	58	15·5	899	14·0	812	1·5	87
Concrete	m^3	87	4·1	356	2·6	226	1·5	130
Formwork	m^2	7	12	84	12	84	—	—
Totals				3254		2277		977

Fig. 17. Comparison between steel-arch support and roof bolting for the New York water tunnel. Costs and working hours are estimated for Swedish conditions

Economy

The economy of the method is best shown by an example: For the New York water tunnel steel lining was first used and then roof bolting under the same geological conditions (see Figs. 12 and 17)[6]. A direct comparison for this section indicates a saving per running metre of tunnel of 445 kg. of steel, 0·10 cu. m. of wood, 1·50 cu. m. of excavation and concrete, and about 29 working hours. Further savings in costs of administration and equipment are accomplished, shortening the time element. If concrete anchors are used for tunnelling through squeezing rock instead of steel ribs placed close to each other the savings will be still greater.

Fig. 16. Failure of roof bolting in the Forçacava machine hall due to incorrect application

Geological Limits of Employment

To illustrate the field in which roof bolting can be successfully used we may refer to Table I.[9]

Concrete anchoring can advantageously be employed even if forepoling is necessary for certain cases of the groups 7 to 9; the anchors, placed as an additional measure to the ordinary support, will be mainly responsible for stopping the squeezing. Consequently the ribs may be lighter and set at greater distances without danger of being destroyed.

Durability

The durability of roof bolting is limited by the corrosion of the steel. As all steel is bound to corrode rapidly in tunnels it is clear that bolting can only be considered as a temporary construction as long as no additional measures

change these conditions. Further, it is also possible that the resistance of the rock will change by chemical or mechanical influences, causing the anchoring to give way, especially when bolting in bad rock.

By grouting the anchors and guniting the surface, the durability of bolting can be very much improved. Further consolidation can be obtained by grouting the surrounding rock. There are different means to grout the bolted construction, as shown in Fig. 18. Either a separate grouting hole has to be drilled for each bolt and a small pipe fixed to the bar to allow the air to escape, or the entrance of the hole is drilled larger in order to allow the grouting pipe to be placed close to the bolt. For instance, the roof of the machine hall of Harsprånget in Sweden (span 18 m.) has been consolidated in this way with 5 m. long bolts, grouted in and the surface netted and gunited. When deciding to grout the bolts it must be borne in mind that the necessary preparations will have to be done at the same time as the holes are drilled. This additional work may probably delay the progress somewhat.

As yet sufficient experience has not been gained regarding the life of grouted-bolt supports, but it can be assumed that subsequent elongation of the bars may cause fine cracks in the grout and allow the steel to be attacked by water. Any circulation of water in the bolted region should consequently be prevented by grouting the surrounding rock.

A durable support may be obtained in this way in chemically sound rock, but in decomposed rock bolting and anchoring must always be considered as a merely temporary construction, and it is doubtless necessary to provide a concrete lining, particularly when dealing with tunnels in the civil-engineering field which are required to last a long time with the least possible maintenance.

In considering the various features of bolting and anchoring it seems that, besides its other advantages, this technique allows a degree of exactness in dealing with the problem of supporting unstable rock that has been unknown hitherto. A very interesting and rewarding field of research work is open for this young and promising technique.

TABLE I

	Condition of Tunnelling Material		Recommended method of support. Bolting and Anchoring	Steel Ribs or European Tunnelling Methods
			No support	
1	Hard and intact	Chemically unaltered	Roof bolting with steel bolts	—
2	Hard, stratified or schistose			—
3	Massive, moderately jointed			—
4	Moderately blocky and seamy			No roof bolting recommended if forepoling necessary.
5	Very blocky and seamy		—	
6	Completely crushed, but chemically intact			
7	Squeezing rock, moderate depth	Chemically altered	Concrete anchors	If forepoling necessary, eventual anchoring as additional measure.
8	Squeezing rock, great depth			
9	Swelling rock			
10	Clay (cohesive soils)		No experience	Forepoling.
11	Sand, gravel (soils without cohesion)	Chemically unaltered	—	Forepoling and breasting by known methods.

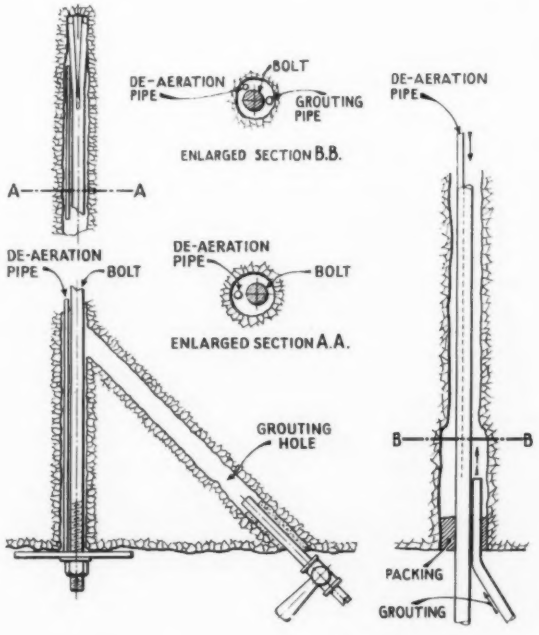


Fig. 18. Methods of consolidating a roof bolt by grouting

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NOTE.—Figs. 12 and 13 are reproduced from *Compressed Air Magazine*

Water-Power Resources of Canada

The Water Resources Division, Engineering and Water Resources Branch, Department of Northern Affairs and National Resources, Canada, has recently issued its customary annual review* of the water-power resources of Canada

THE recorded water-power resources of Canada are now shown to total more than 29,000,000 h.p. under conditions of low stream flow and of nearly 51,000,000 at average flow, the latter figure representing a feasible turbine installation of nearly 66,000,000 h.p. The total turbine installation at the end of 1953 is given as 14,929,074 h.p., indicating that less than 23 per cent. of available resources has as yet been developed. During 1953, 638,012 h.p. of new capacity came into operation and good progress was made on other new developments; additional projects were also being investigated or planned.

The accompanying Table gives the total water-power resources of Canada and the present total capacity of all water-power plants in the country. The totals of installed capacity are based upon the manufacturer's rating of each individual turbine and water-wheel, if this information is available. The provincial totals are subject to revision from year to year to allow for the dismantling of obsolete plants and for the correction of errors in listed plant capacities, as well as for the addition of new plants or units.

TABLE I.—AVAILABLE AND DEVELOPED WATER POWER IN CANADA, YEAR ENDING 1953

Province or Territory	Available 24-hour power at 80% efficiency — h.p.		h.p. Installed Turbine Capacity
	At Ordinary Min. Flow	At Ordinary 6-Months Flow	
1	2	3	4
British Columbia -	7,023,000	10,998,000	1,496,518
Yukon & N.W.T.	382,500	814,000	32,440
Alberta - -	508,000	1,258,000	207,960
Saskatchewan -	550,000	1,120,000	109,835
Manitoba - -	3,333,000	5,562,000	716,900
Ontario - -	5,407,000	7,261,000	4,006,686
Quebec - -	10,896,000	20,445,000	7,719,122
New Brunswick -	123,000	334,000	164,130
Nova Scotia -	25,500	156,000	162,433
Prince Edward Is.	500	3,000	1,900
Newfoundland -	958,500	2,754,000	311,150
Totals - -	29,207,000	50,705,000	14,929,074

Provincial Distribution of Water Power

An analysis of this table shows that important resources are well ditsributed throughout, the country and that, even at the present stage of development, considerable blocks of hydro-electric power are being produced in all provinces, with the exception of Prince Edward Island, where the resources are small. The provinces of Ontario and Quebec contain nearly 55 per cent. of the total potential and more than 78 per cent. of the developed power, about 32 per cent. of their total resources being now developed.

British Columbia, traversed by three distinct mountain ranges and with, on the whole, a high rate of precipitation, has many mountainous rivers which offer opportunity for future development. The province ranks second in available resources and is exceeded only by Quebec and Ontario in installed capacity. Practically all present developments are located in the southern portion of the province, the largest being the Bridge River plant of the British Columbia Electric Co. Ltd., 186,000 h.p. The British Columbia Power Commission, which was organised in 1945, has become an important power-producing and distributing agency.

The water powers of the Yukon and Northwest Territories, although of considerable extent, are so remotely located as to limit their present commercial development to local mining uses. However, owing to lack of native fuel and to transportation difficulties, they are of special importance in the development of mining areas such as Yellowknife, Northwest Territories, and Mayo, Yukon Territory.

In Alberta, the larger hydro-electric developments from which Calgary Power Limited serves a large part of the southern portions of the province, are located on the Bow River and tributaries. The greater part of water-power resources is located in the northern half of the province, rather remote from present centres of population.

In Saskatchewan, water-power developments are confined to mining uses in the northern areas, in which water-power resources are abundant. The transmission network of the Saskatchewan Power Corporation of the Provincial Government, serving the more settled areas, is supplied exclusively by fuel-power plants. Large reserves of coal, oil, and natural gas are located in both Saskatchewan and Alberta; these fuels provide the more economic sources of power in many parts of both provinces, particularly in southern Saskatchewan.

Of the Prairie Provinces, Manitoba has the largest water-power resources, there being great potential power on the Saskatchewan, Nelson, and Churchill Rivers. The larger present developments are located on the Winnipeg River and serve Winnipeg, adjacent municipalities, and the transmission network of the Manitoba Power Commission. The Commission is at present serving about 400 municipalities and is carrying out a vigorous programme of rural electrification, it being estimated that 39,500 farms were receiving service at the end of 1953.

Ontario has large power resources, being exceeded in this respect only by Quebec and British Columbia. It has developed about 42 per cent. of its potential and ranks second in power production among the provinces. The Hydro-Electric Power Commission of Ontario is the greatest power-producing and distributing organisation in Canada; it operates 60 hydraulic generating stations with a total capacity of more than 3,000,000 h.p., the largest being the Sir Adam Beck Generating Station No. 1 on the Niagara River of 560,000 h.p.; in addition, nearly 1,000,000 h.p. is purchased on contract. At the end of 1953, power was

*Bulletin No. 2405, "Water-Power Resources of Canada." Obtainable free of charge on application to the Chief, Water Resources Division, Department of Northern Affairs and National Resources, Ottawa.

being supplied to roughly 1,250 municipalities; rural electrification receives special consideration and approximately 133,000 farms are now being served.

The Province of Quebec is richest in water-power resources, containing more than 40 per cent. of the total recorded for Canada. Quebec also ranks highest in developed power, its present installation of 7,719,122 h.p. being nearly 52 per cent. of the total for all provinces and representing the development of about 29 per cent. of its presently recorded resources. Two of the larger hydro-electric plants in the world, and ones which exceed in size all others in Canada, are located in this province. The Quebec Hydro-Electric Commission's Beauharnois development on the St. Lawrence River has a present capacity of 1,408,000 h.p. and the Shipshaw plant of the Aluminum Company of Canada on the Saguenay River is rated at 1,200,000 h.p. Power production in the province is greatly facilitated by the regulation of stream flow by the Quebec Streams Commission through the storage dams it operates or controls. Rural electrification has made good progress with about 94,000 of the 150,000 farms in the province now receiving service; further extensions through co-operative distribution systems are being fostered by the Quebec Rural Electrification Bureau.

The water powers of New Brunswick and Nova Scotia, although small in comparison with the resources of other provinces, constitute a valuable source of power; both provinces have numerous rivers upon which moderate power developments may be made within economic transmission distance of the principal cities and towns; other sites are advantageously situated for the utilisation of timber and mineral resources. These provinces also are favoured with abundant indigenous coal supplies. In Prince Edward Island, there are no large streams and consequently water-power sites are limited in size to those used for small mills.

Owing to lack of stream-flow data, Newfoundland's important water-power resources have been only tentatively evaluated. On the island, while the rivers are short, topography and run-off conditions are favourable to power development; in Labrador, the Hamilton River has a high power-potential. Considerable development has taken place on the island, the larger developments having been made to serve the pulp-and-paper industry.

Progress in Development during 1953

Although a tremendous amount of hydro-electric construction was carried out in Canada during 1953, the net increase in installed capacity of 623,194 h.p. was somewhat lower than that of recent years. However, plants and extensions which were under construction for operation in 1954 total 1,500,000 h.p. and those for later years about an equal amount. Projects undertaken or under investigation at rather remote locations emphasise the future economic value of other undeveloped sites in unsettled regions. Construction in the field of power distribution and in the building of thermal-electric plants also was active.

Overall progress in each of the provinces, principally covering hydro-electric development, is outlined below.

British Columbia

The British Columbia Power Commission completed the installation of the final two units each of 28,000 h.p. in the John Hart development on the Campbell River, Vancouver Island, bringing total capacity to 168,000 h.p. To provide additional storage for this development, surveys and drilling were carried out at Buttle Lake for a dam to be built in 1954. The redevelopment of the dismantled Puntledge River plant has been undertaken and a single unit of 35,000 h.p. driving a 30,000 kVA generator will be installed, with initial operation probably late in 1954. Contracts have been awarded and work commenced on a development on the Spillimacheen River to consist of three units with a total capacity of 5,500 h.p. for 1955 operation. The Whatshan plant of 33,000 h.p. was badly damaged by two devastating landslides during August and restoration to full operation is not expected for some months. Transmission lines built during the year include about 100 miles of 63 kV line from Vernon to Kamloops.

The British Columbia Electric Co. Ltd. continued with the installation of a fourth 62,000 h.p. unit in its Bridge River plant for 1954 operation. The raising of the La Joie storage dam to provide increased reservoir capacity also was continued. Surveys were made covering a proposed development on Seton Creek further to utilise the water diverted through the Bridge River plant; active construction will begin in 1954 and it is planned to have the single unit of 58,000 h.p. driving a 42,000 kVA generator, for operation in 1956. A 4,860 h.p. turbine, which served a few years ago in a temporary capacity at Bridge River, has been reinstalled in the Jordan River No. 1 plant, bringing the capacity to 38,985 h.p. The company extended its 60 kV lines by about 25 miles and built new substations at several locations.

The Consolidated Mining and Smelting Company of Canada Limited expects to complete the construction of its Waneta development on the Pend d'Oreille River early in 1954. The plant will contain two turbines each of 105,000 h.p. and ultimately two additional units may be installed.

Favourable progress has been made by the Aluminum Company of Canada on its great Kemano-Kitimat project involving the diversion of the headwaters of the Fraser River through the Coastal Range. The drilling of the 10-mile 25 ft. diameter diversion tunnel from Tahtsa Lake and of the penstock tunnel was essentially completed at the year's end. The underground power-house has been completed and the work of installing three 140,000 h.p. turbines and 106,000 kVA generators is well advanced for operation in May 1954. The 50-mile transmission line from Kemano to Kitimat has been virtually completed. The spillway for the Kenney Dam on the Nechako River is now ready for operation. No definite commitment beyond the present installation of 420,000 h.p. has been made although ultimate capacity is more than 2,000,000 h.p.

Yukon Territory

The Yukon Hydro Company Limited, serving the town of Whitehorse, has added a Pelton wheel of 940 h.p. driving an 875 kVA generator to its Porter Creek plant, to bring capacity to 1,390 h.p.

Surveys and investigations towards a major hydro-electric development, involving the storage of Yukon River headwaters and their diversion through the Coastal Range, were carried out during the summer of 1953 and will be continued in 1954 by Ventures

Limited and its subsidiary companies, Frobisher Limited and Quebec Metallurgical Industries Limited. Preliminary planning indicates that initially a development of about 25,000 h.p. may be made on one of the rivers on the Pacific slope in northern British Columbia.

Alberta

Calgary Power Limited has under installation a third unit rated at 33,000 h.p. in its Ghost plant on the Bow River, with operation scheduled for June 1954, which will bring plant capacity to 69,000 h.p. Construction is proceeding on the Bearpaw development, on the Bow River near Calgary, to consist of one unit of 22,000 h.p. for operation in late 1954 or early 1955. In connection with the Spray River development, two pump stations are being installed to raise water from Goat Creek into the Spray canal, thus substantially increasing the power output of the Spray and Rundle plants. Extensions of the transmission system included 84 miles of 138 kV line and 24 miles of 66 kV line. The company now serves 14,000 farms.

Manitoba

No new hydro-electric units were brought into operation in 1953, but the Manitoba Hydro-Electric Board continued construction on its McArthur Falls development of 80,000 h.p. on the Winnipeg River. Four units each of 10,000 h.p. are scheduled for operation by December 1954 and plant completion in 1955.

In connection with the Laurie River development of Sherritt-Gordon Mines Limited, a control and diversion dam was completed on the Loon River. Surveys for a new development were made at a site about seven miles above the present plant.

The Manitoba Power Commission continued to expand its distribution system; new transmission lines built include 85 miles at 115 kV and 64 miles at 66 kV.

Ontario

The Hydro-Electric Power Commission of Ontario completed its Otto Holden Generating Station on the Ottawa River above Mattawa by installing the eighth unit of 33,000 h.p., bringing total capacity to 264,000 h.p.

Good construction progress was made on the Commission's 12-unit 1,260,000 h.p. Sir Adam Beck Generating Station No. 2 on the Niagara River at Queenston, with initial operation scheduled for 1954. Excavation of the two large tunnels and of the canal and forebay was practically completed; concrete placing in the head works, tunnels, and power-house was well advanced; and four penstocks and part of the power-house superstructure were erected. Plans for the development include a 15,000-acre-ft. pumped-storage reservoir adjacent to the forebay.

At the Commission's Pine Portage Generating Station on the Nipigon River, two additional units each of 45,000 h.p. were being installed for operation in the autumn of 1954. Preliminary construction was begun on a development at Manitou Falls on the English River which will have a capacity of 46,000 h.p. in three units for 1956 operation.

Extensions to the Commission's transmission system include 42 miles of line at 230 kV, 204 miles at 115 kV and 252 miles at lower voltage. An interconnection with the Detroit Edison Company by high line across the Detroit River was completed in September.

The Great Lakes Power Company completed the construction of its two-unit 20,000 h.p. development at Scott Falls on the Michipicoten River. Good progress also was made on the company's McPhail Falls project, a few miles upstream on the same river, operation of this two-unit 15,000 h.p. plant being planned for late 1954. The Ontario and Minnesota Power Company has undertaken the modernisation of its Rainy River plant which will increase capacity by about 650 h.p. in 1954.

Quebec

The Quebec Hydro-Electric Commission completed its Beauharnois Power-house No. 2 by a two-unit addition of 111,000 h.p., bringing overall capacity of the development to 1,408,000 h.p. Dredging operations in the intake canal are being continued but no definite commitments for further capacity have been made.

The Commission also reports that substantial progress was achieved on a number of its other projects. On the Upper Ottawa River, the construction of the two-unit 32,000 h.p. Rapid II development is proceeding on schedule and operation is expected in June 1954. Construction was commenced on a 1,200,000 h.p. hydro-electric development on the Bersimis River about 62 miles above its mouth, with 300,000 h.p. to be developed initially for 1956 operation. Part of the output of this plant will be transmitted to the Gaspe Peninsula by a 32-mile submarine cable which is to be laid in 1954 on the bed of the St. Lawrence River. Transmission lines built in 1953 included 31 miles of double-circuit 120 kV line and 18 miles at 115 kV; other high-voltage lines were under construction.

The Aluminum Company of Canada Limited completed its 285,000 h.p. Chute-a-la-Savanne development on the Peribonka River by bringing into operation the remaining four units each of 57,000 h.p. The station is tied-in with the Isle Maligne plant on the Saguenay River by a 154 kV line.

The Price Brothers and Company Limited brought into operation their two new plants on the Shipshaw River, 70,000 h.p. in two units at Chute-des-Georges, and 9,000 h.p. in one unit below Lac Brochet.

The Manicouagan Power Company completed the installation of the second unit of 56,200 h.p. in its plant near the mouth of the Manicouagan River, which is designed for six units, to be added as required.

The Shawinigan Water and Power Company has undertaken the installation for 1955 operation of one additional unit in each of its Rapide Blanc, La Trenche, and La Tuque plants, having a combined total of 158,500 h.p. The diversion works to provide flow from the Megiscane and Susie Rivers into Gouin Reservoir were completed in August. About 52 miles of 110 kV transmission line were built in 1953 and 80 miles of 220 kV line were under construction.

The Ste. Marguerite Power Company was proceeding with the construction of a two-unit 17,000 h.p. plant on that river for 1954 operation. The City of Megantic had work in progress on the development of 4,500 h.p. on the Chaudiere River, with operation of one unit of 2,250 h.p. expected in May 1954. The Quebec Rural Electrification Bureau expected to complete early in 1954 a two-unit development of

1,200 h.p. on the Petites Bergeronnes River at Lac des Sables.

The MacLaren-Quebec Power Company completed the building of a new storage dam on the Lievre River at the outlet of Kiamika Lake, and one was under construction on the Mitis River by the Lower St. Lawrence Power Company.

The Gatineau Power Company completed an interconnection with the Quebec Hydro-Electric Commission's system by building a 30-mile 110 kV line from Lachute to Cedars. Other extensions included 16 miles of new and 15 miles of rebuilt 26·4 kV line.

The Quebec Streams Commission carried out stream-flow regulation on a number of important rivers on which storage dams are operated. Reconstruction of dams on the St. Francois, Mitis, and Manouane Rivers was completed, and repairs were made to the La Loutre power plant. Preliminary investigations of water-power sites on the Rupert, Chamouchouane, and Bazin Rivers were carried out; also flood-control studies on the Ste. Anne de la Perade and Salmon Rivers. Flood-protection works were built at a number of locations throughout the province.

New Brunswick

The New Brunswick Electric Power Commission brought into operation in April its two-unit 27,000 h.p. plant at "The Narrows" on the Tobique River. Active investigations were carried out on the Beechwood site on the St. John River with a view to building a plant initially of two units each of 48,000 h.p. Surveys also were made of a site of about 10,000 h.p. on the Sisson River, a tributary of the Tobique River. Main transmission lines built in 1953 include 64 miles of 69 kV line from the Tobique plant to Woodstock and to Grand Falls; also a 38-mile line from Alardville to Six Roads.

The St. George Pulp and Paper Co. Ltd. carried out a modernisation programme, resulting in an increase in capacity of 2,812 h.p. in its plant on the Magaguadavic River. The plant is now rated at 7,812 h.p. in four units.

Nova Scotia

No new developments were completed in 1953, but the Nova Scotia Light and Power Co. Ltd. had under construction for 1954 operation a plant of 9,000 h.p. on the Nictau River near Middleton. During the year the company completed the installation of an additional unit of 22,000 kW in its steam plant at Halifax; it is planned further to install a unit of 25,000 kW for 1955 operation. New transmission lines constructed included 20 miles of 69 kV line from Black River to Berwick.

The Nova Scotia Power Commission is proposing to develop 6,000 h.p. under 22 ft. head on the Mersey River near Liverpool for 1955 operation. For its steam plant at Trenton, the Commission has on order a turbo-generator of 20,000 kW for installation in 1955.

Newfoundland

The Newfoundland Light and Power Company completed the construction of its second plant on the Horsechops River, 10,000 h.p. in one unit. Investigations have been carried out on Piper's Hole River on which there are three sites totalling about 31,000 h.p. A new 66 kV transmission line from Rocky Pond to Mobile was completed. A diesel unit of 3,850 h.p. has been installed at St. John's for standby purposes.

The Anglo-Newfoundland Development Company has completed the modernisation of its Bishop's Falls development on the Exploits River, resulting in an increase in capacity of 6,000 h.p., making a total of 21,900 h.p.

The Iron Ore Company made favourable progress on its development at Menihek Rapids on the Ashuanipi River, a tributary of the Hamilton River in Labrador, and it is expected that the plant of 12,000 h.p. in two units will be in operation in August 1954; ultimately two additional units may be installed. A 26-mile 110 kV line from the plant to Knob Lake, which was expected to be completed in 1953, will be operated initially at 66 kV.

The Union Electric Light and Power Company carried out an investigation of a site on the Trinity River, at which it is proposed to develop 2,000 h.p. under 260 ft. head.

During the present century, the growth in the total of hydraulic installations in Canada has been continuous, and the rate of growth has tended to accelerate. In the period 1900-1905, the average annual increase was only 56,000 h.p., but this was sharply stepped up in subsequent years, largely due to improvements in electrical transmission and the building of large central stations. During the period 1906-1922 inclusive, development proceeded at a fairly uniform rate of 150,000 h.p. per year. As a result of the heavier demand for electricity during the prosperous 1920's, the rate of installation increased sharply, and continued at the nearly uniform rate of 377,000 h.p. per year for the period 1923-1935 inclusive. As large-scale hydro-electric projects take considerable time to complete, there is a lag between construction and demand, the latter responding quickly to general economic conditions. When the demand for power fell off during the 1930's, projects under way were carried to completion, but the result of the economic depression is reflected in the low rate of installation during the years 1936-1939 inclusive. The great demand for power for war purposes accounts for the high average rate of increase of 481,000 h.p. per year during the period 1940-1943 inclusive. Few developments were undertaken in the later war years, or in the immediate post-war period, so that only a small amount of new capacity came into operation from 1944 to 1947 inclusive. However, the results of the later post-war programme of construction are apparent in the amount of growth in the years 1948 to 1953, the average rate being about 740,000 h.p. per annum. Present programmes of expansion indicate a continuation of this rate of growth for some years. It may be noted that in 1953, 90 per cent. of the total installation of water-power plants in Canada was of the central-station type as compared with 33 per cent. in 1900.

Developed Power in Relation to Population

Table II overleaf lists the estimated population of Canada by provinces as of June 1, 1953, for comparison with the installed capacity of present water-power developments. The average installation per thousand of population is 1,010 h.p., which places Canada in an outstanding position in respect to water-power development and, on this basis, second only to Norway among countries of the world. In total water-power installation, Canada is exceeded only by the United States.

The per capita figures of provincial installation partly reflect the extent and character of the utilisation of water power in each province. The Province of Quebec, which is second in population, has the largest total installation and also the highest rate, 1,808 h.p. per 1,000 population; large power-consuming industries such as aluminium production and pulp-and-paper manufacture are located in the province. Yukon and Northwest Territories, with very sparse populations but with a relatively heavy power-demand for gold mining, show an abnormal rate of 1,298 h.p., which is scarcely comparable to those of the provinces. British Columbia, with a comparatively small population, ranks second among the provinces in per capita installation, 1,217 h.p., chiefly owing to the large blocks of power required for its mining, metallurgical, and forest-product industries. Manitoba, sixth in population but fourth in total installation, has an average installation of 886 h.p. per 1,000 population; a large part of the power is consumed in the industrially important City of Winnipeg. Ontario, with the largest population, is second in total hydraulic installation, and has a rate of 818 h.p. per 1,000 population; its power-consuming industries are very diversified. The comparatively high rate of 812 h.p. in Newfoundland is due principally to large pulp-and-paper installations. New Brunswick has a rate of 306 h.p., and Nova Scotia, 245 h.p. per 1,000 population; the water-power resources of these provinces are rather limited, and considerable power is developed from coal. In Alberta and Saskatchewan, with rates of respectively 208 h.p. and 128 h.p. per 1,000 population, water-power resources are located largely in the northern parts of the provinces, rather remote from present main centres of population, which are served largely by thermal-electric plants. Prince Edward Island has only minor water-power resources, which accounts for the low rate of installation, 18 h.p. per 1,000 population.

TABLE II.—TOTAL HYDRAULIC INSTALLATIONS IN RELATION TO POPULATION

Province or Territory	Installed Capacity h.p.—1953	Population June 1, 1953	Installation per thousand population h.p.
1	2	3	4
British Columbia	1,496,518	1,230,000	1,217
Yukon & N.W.T.	32,440	25,000	1,298
Alberta	207,960	1,002,000	208
Saskatchewan	109,835	861,000	128
Manitoba	716,900	809,000	886
Ontario	4,006,686	4,897,000	818
Quebec	7,719,122	4,269,000	1,808
New Brunswick	164,130	536,000	306
Nova Scotia	162,433	663,000	245
Prince Edward Is.	1,900	106,000	18
Newfoundland	311,150	383,000	812
Canada	14,929,074	14,781,000	1,010

The wide and favourable distribution of water power, and the versatility of low-cost hydro-electric power developed from this source have been vital factors in the rapid industrialisation of the country and in facilitating the attainment of a high standard of living by its citizens. The numerous developments at present under way or planned confirm the continuation of this trend, while further opportunitiees for future progress are offered by the large reserves of undeveloped power.

Copies of the complete annual bulletin may be obtained free of charge upon application to The Chief, Water Resources Division, Department of Northern Affairs and National Resources, Ottawa.

Congress on Wave Research

The annual reunion of the Council on Wave Research of The Engineering Foundation at the University of California is to be held this year from September 8 to 11 at Grenoble—a new departure as it is the first reunion to be held outside the United States. The sessions will take place at the Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique, 44, Avenue Félix Viallet, Grenoble. The President of the entire Congress will be the Dean of the University of California, Dr. O'Brien, and he will be assisted by the General Secretary, Professor Johnson. A local committee is responsible for the material organisation of the meeting and for general co-ordination in Europe. This committee includes representatives of the University, the Harbour Division of the Ministry of Public Works, the Study and Research Department of Electricité de France, and the Etablissements Neyrpic.

Thc present programme covers, generally speaking, the various problems raised by protection and development of sea coasts: study of the wave, coast formations, transport of suspended materials, planning and construction of sea structures.

The last date on which papers can be accepted is June 30, 1954. The texts should be sent to the General Secretary of the Congress (Professor Johnson, University of California, Berkeley, Calif., U.S.A.); papers from Europe may also be submitted to the local Organising Committee at the following address: Coastal Engineering Congress, Ecole Nationale Supérieure d'Electrotechnique et d'Hydraulique, 44-46, Avenue Félix Viallet, Grenoble (France).

Power Link between U.S.A. and Canada

Linking a thermal generating system in America with a hydro-electric network in Canada is a set of power cables newly spanned across the St. Clair river. It connects the facilities of the Detroit Edison Company at Marysville to those of the Hydro-Electric Commission of Ontario at Sarnia.

Constituting one of the world's major exchanges of electric supply between nations, the two systems will exchange power on a day-to-day basis during off-peak periods. The lines at Marysville permit an interchange capacity of between 200 and 300 MW. The project also includes a connection between the two parties across the Detroit-Windsor link, so that one nation can supply the other with considerable emergency power in the event of a disaster.

Rapier Mobile Crane. A new publication issued by Ransomes & Rapier Limited describes and illustrates their " 5 Super " mobile crane which is designed for loads of up to 5 tons (15,000 lb. American rating). A full specification is given, and the equipment can be powered either by diesel-electric or petrol electric, and either solid or pneumatic tyres can be provided. A travel speed of 6½ m.p.h. can be maintained.

Some Aspects of Water Hammer

R. Silvester, B.A., B.E., A.M.I.E.Aust., of the University of Western Australia, presents a simplified graphical solution for water-hammer problems and discusses various problems relating to closure characteristics.

IN this article four aspects of the water-hammer problem are discussed: (a) A simplified method for graphically solving water-hammer problems is illustrated; (b) A comparison is made of linear velocity reduction with non-linear; (c) A method of deriving the time-velocity diagram for a valve is shown. (d) The effect on the closure characteristic and hence the water-hammer tendency of a length of line downstream of the control valve is considered.

Symbols Used

A — area of pipe downstream of the valve (sq. ft.).
a — area of valve at any time (sq. ft.).
B and K — constants.
C — coefficient of area for valve.
d — diameter of line downstream of the valve (ft.).
f — friction factor of line downstream of the valve (dimensionless).
g — acceleration due to gravity (32·2 ft./sec.^{2}).
H — pressure head in pipe upstream of valve (ft.).
h_V — friction head loss in valve (ft.).
h_L — friction head loss in line downstream of the valve (ft.).
h_T — $h_V + h_L$.
L — length of line subject to water hammer (ft.).
l — length of line downstream of the valve (ft.).
R_n — Reynolds number $\frac{Vd}{\nu}$ where ν is the kinematic viscosity of the liquid (ft.^{2}/sec.).
V — velocity in pipe (ft./sec.).
v — velocity of pressure wave (ft./sec.).

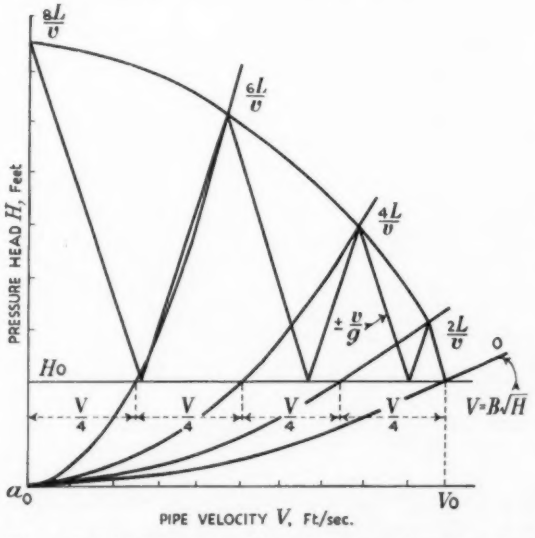

Fig. 1. Original method of drawing water-hammer chart

Suffix $_o$ to any symbol indicates initial conditions, that is the valve fully open.

Simplified Graphical Solution

The original method of drawing water-hammer charts is illustrated in Fig. 1. The necessity for drawing parabolas for various valve openings turns engineers away from using the graphical solution to the more conservative instantaneous-closure formula.

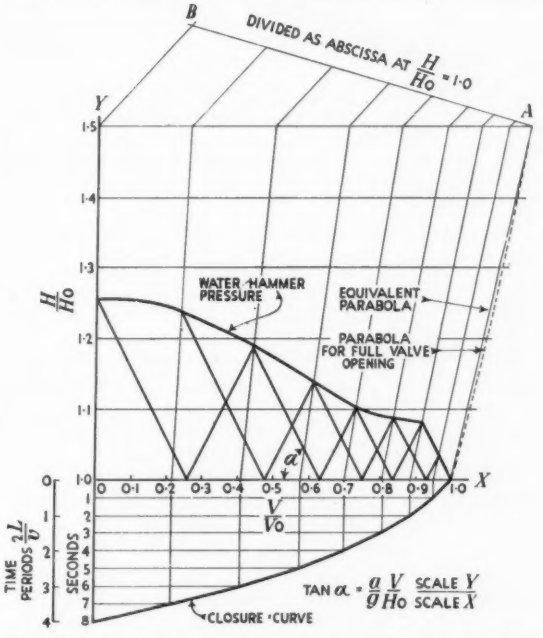

Fig. 2. Water-hammer chart obtained by using straight lines, or "equivalent parabolae" instead of true parabolae

Even the improved diagram with ordinate H/H_o and abscissa V/V_o entails drawing parabolas, but the ratio scales make for smaller figures and a more universal application.

To simplify water-hammer charts it is suggested that the parabolas be replaced by straight lines, to which they approximate when the scales H/H_o and V/V_o are used. In Fig. 2 points on the parabola for $V/V_o = 1{\cdot}0$ when $H/H_o = 1{\cdot}0$ and $1{\cdot}5$ are joined by the true parabola (dotted) and a straight line (full), which, it is suggested, can replace it without undue error. This straight line will be termed the equivalent parabola or just the "parabola."

Any error that occurs for the initial conditions will be reduced as the Y axis is approached and the nearer the point A can be located to the abscissa.

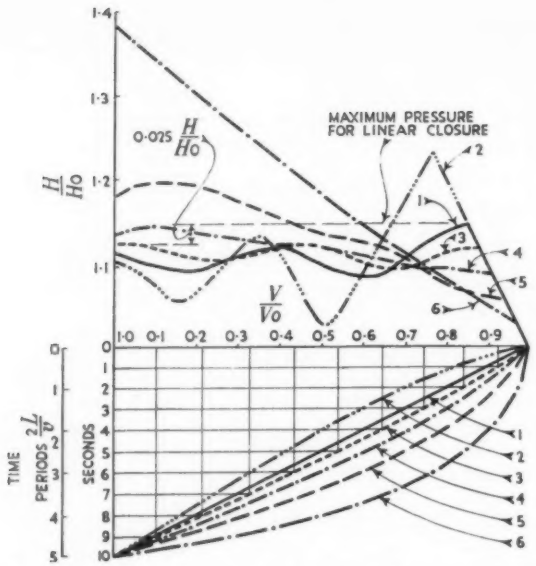

Fig. 3. Linear and non-linear closures in a system in which the water-hammer curve for linear closure is flat

To obtain the initial "parabola" we have for the valve generally

$$V = B\sqrt{H} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

or $\frac{V}{V_o} = \frac{B}{B_o}\sqrt{\frac{H}{H_o}}$ and since at full valve opening $\frac{B}{B_o} = 1$

then $\frac{V}{V_o} = \sqrt{\frac{H}{H_o}}$ e.g. when $\frac{H}{H_o} = 1{\cdot}5 \qquad \frac{V}{V_o} = 1{\cdot}223$

If the velocity is to be reduced directly with time (linear closure), the abscissa ($H/H_o = 1{\cdot}0$) is divided into periods of closure ($2L/v$) and at $H/H_o = 1{\cdot}5$ (say) is divided proportionately by constructing such a line as AB (Fig. 2) marked from the abscissa.

The water-hammer chart proceeds as normal from this point, the slope of the pressure-wave lines being

$$\pm \frac{a}{g} \cdot \frac{V_o}{H_o} \cdot \frac{\text{Scale } Y}{\text{Scale } X}$$

Linear and Non-Linear Closure

It will be noticed in Fig. 2 from the time-velocity curve that closure in this instance is not linear. The method of accounting for non-linear closure is apparent in the diagram, for instead of the time intervals intersecting a straight line they intersect a curve and the resulting "parabolas" are spaced unevenly across the diagram.

The effect that a non-linear closure has on water-hammer pressure compared with linear closure will depend firstly upon the shape of the closure curve, and secondly upon the water-hammer characteristic of the line.

The curve may be either side of the straight-line closure (cf. curves Nos. 2 and 3—6 in Fig. 3), or it may accelerate cut-off at different stages (cf. curves 2 and 4 in Fig. 4). It may even be an S-shape cutting the straight-line closure (such a curve has not been drawn).

Regarding the line characteristic, consider a linear closure, the resulting water-hammer curve may be flat (full line, Fig. 3) or rising continuously (full line, Fig. 4). This shape is determined mainly by the difference in slope between the pressure-wave line and the "parabolas." When the difference is large the flat curve results and when it is small the rising curve results. For the two slopes to approach each other requires the value of V_o/H_o to increase, since when scale is eliminated the slope of the pressure-wave curve is given by $\frac{a}{g} \cdot \frac{V_o}{H_o}$ of which $\frac{a}{g}$ is relatively constant.

From Fig. 3 it is seen that a closure curve such as No. 2 will spread the "parabolas" out at the commencement of closure and so allow the pressure to build up more in the first period, thus adding to the maximum pressure obtained previously. Curve No. 3 has the opposite effect. It reduces the initial pressure and actually reduces the maximum at any stage to $0{\cdot}025\ H/H_o$ below that for straight-line closure. But continuance of this tendency (curves Nos. 4, 5 and 6) although decreasing the initial pressure will build it up near the end of the cut-off period, giving a greater maximum pressure.

Although closure curve No. 2 in Fig. 3 increases the maximum pressure above that for linear closure, a similar curve (No. 2 in Fig. 4) decreases this maximum in a rising pressure curve (in this instance it decreases it by $0{\cdot}175\ H/H_o$). Curves on the other side of the linear closure have not been drawn in Fig. 4 because they obviously would increase the tail-end pressure and hence the maximum obtained. Curve No. 4, which might well represent a gate valve closure, builds up a large pressure in the centre of the closing period.

From both Figs. 3 and 4 it should be obvious that

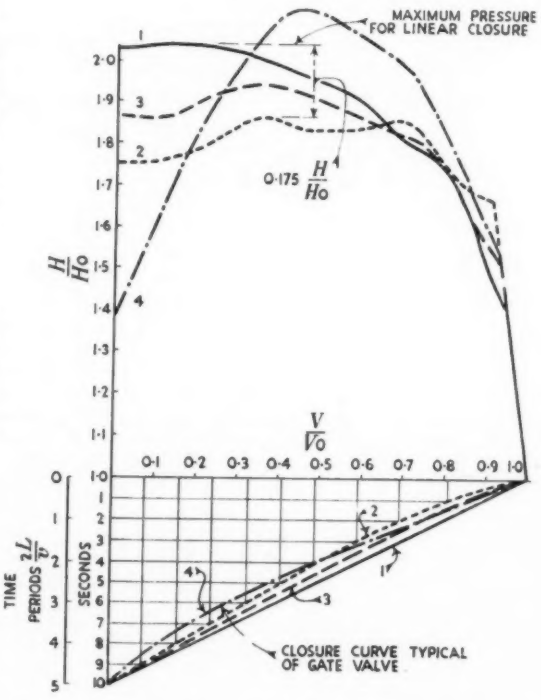

Fig. 4. Linear and non-linear closures in a system in which the water-hammer curve for linear closure is continuously rising

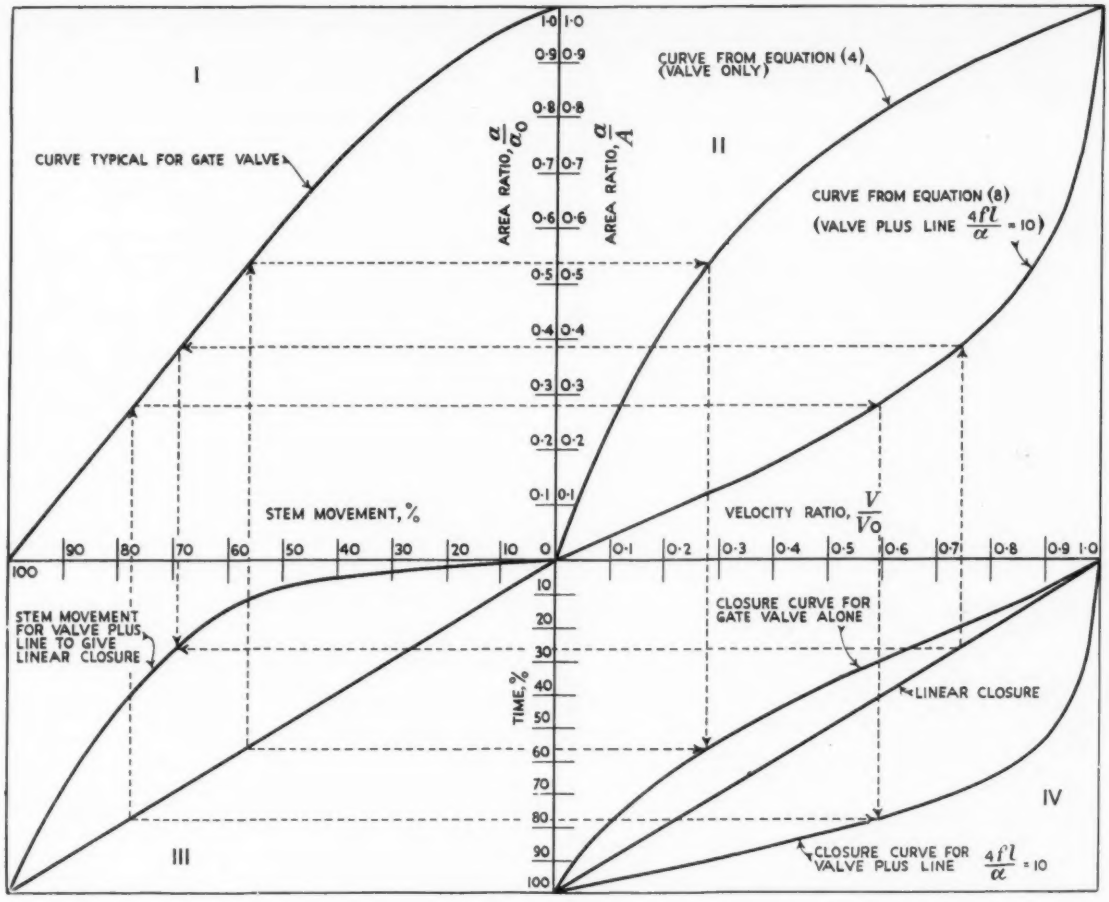
I
II
III
IV
CURVE TYPICAL FOR GATE VALVE
CURVE FROM EQUATION (4) (VALVE ONLY)
CURVE FROM EQUATION (8) (VALVE PLUS LINE $\frac{4fl}{d} = 10$)
AREA RATIO, $\frac{a}{a_o}$
AREA RATIO, $\frac{a}{A}$
STEM MOVEMENT, %
VELOCITY RATIO, $\frac{V}{V_o}$
TIME, %
STEM MOVEMENT FOR VALVE PLUS LINE TO GIVE LINEAR CLOSURE
CLOSURE CURVE FOR GATE VALVE ALONE
LINEAR CLOSURE
CLOSURE CURVE FOR VALVE PLUS LINE $\frac{4fl}{d} = 10$

Fig. 5. Curves relating stem movement, area of opening, time, and velocity ratio for a valve

a linear closure, that is a reduction of velocity directly with time, gives near to the minimum water-hammer pressure and any methods to bring this about are advantageous.

The Time-Velocity Curve for a Valve

This can be obtained in two ways.

(i) By a practical test carried out on a valve.

(ii) By finding the stem movement and area-of-opening relationship for the valve.

(i) The valve, or its model, can be placed on a line and for various degrees of stem movement the head loss through the valve and the pipe velocity can be recorded. The velocity readings are then modified to give similar head losses by using equation (1) ($V = B\sqrt{H}$). By combining the curves stroke-velocity and time-stroke the graph of time-velocity is easily obtainable.

(ii) The stroke-area curve for a valve, if not obtainable from the manufacturer, can be measured from drawings of the various disc or cone positions. Typical curves for various types of valve can be seen in Reference No. 2.

Next, it is necessary to express the head loss through the valve at various openings for different pipe velocities. This is given by

$$h_v = \frac{\left(\frac{VA}{Ca} - V\right)^2}{2g} = \frac{V^2}{2g}\left(\frac{A}{Ca} - 1\right)^2 \quad . \quad . \quad (2)$$

since the velocity-area curve is required for a constant head loss, we have

$$V = \frac{K}{\left(\frac{A}{Ca} - 1\right)} \quad . \quad . \quad . \quad (3)$$

and since a ratio of velocity at any opening to that at full opening is required, we have

$$\frac{V}{V_o} = \frac{\left(\frac{A}{C a_o} - 1\right)}{\left(\frac{A}{Ca} - 1\right)} \quad . \quad . \quad . \quad (4)$$

In diagram II of Fig. 5 equation (4) has been plotted for values of $a_o = A$ and $C = 2/3$.*

It should be noted that a_o does not necessarily equal A, in fact, in most installations the diameter of the valve installed is generally smaller than that of the line. The effect of this reduction will be studied in the final section of this article.

* The assumption that C remains constant for all openings of valves is being tested at the Hydraulics Laboratory of the University of Western Australia at present.

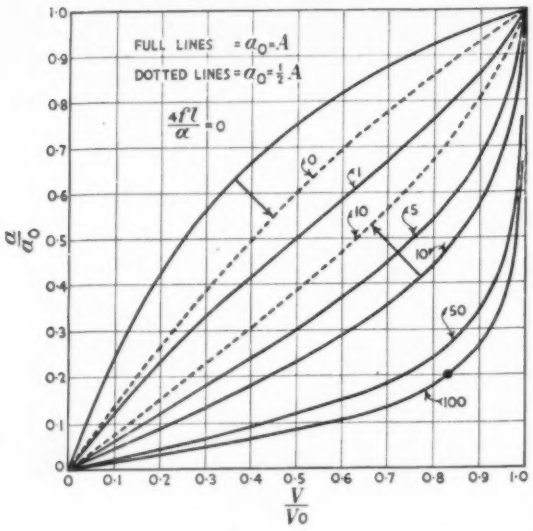

Fig. 6. Effect of downstream pipeline control

The procedure to obtain the velocity-time curve from the above information and the known time-stroke curve is illustrated by arrows in Fig. 5. A stroke-area curve typical of a gate valve is shown in diagram I. Using the curves referring to the valve alone, with the stem moved uniformly with time, as illustrated in diagram III, a closure curve is obtained in diagram IV similar to curve No. 4 in Fig. 4.

Valve plus Downstream Pipeline Control

The velocity of the flow through a pipe with a valve in it is determined by the friction in both the valve and the line. When fully open the valve has little or no control on the flow, and generally will not assume such control until it is partly closed.

The head loss through the valve is given by equation (2)

$$h_v = \frac{V^2}{2g}\left(\frac{A}{Ca} - 1\right)^2 \quad . \quad . \quad (2)$$

The loss through the pipe is given by

$$h_L = \frac{4fl}{d}\,\frac{V^2}{2g} \quad . \quad . \quad . \quad . \quad (5)$$

using Darcy's formula.

The total loss in the system is

$$h_T = h_v + h_L = \frac{V^2}{2g}\left[\left(\frac{A}{Ca} - 1\right)^2 - \frac{4fl}{d}\right]. \quad (6)$$

Since curves are required for constant head loss, we have

$$V^2 = \frac{K}{\left[\left(\frac{A}{Ca} - 1\right)^2 - \frac{4fl}{d}\right]} \quad . \quad (7)$$

$$\text{or } \frac{V}{V_o} = \frac{\sqrt{\left(\frac{A}{Ca_o}\right)^2 - \frac{4fl}{d}} - 1}{\sqrt{\left(\frac{A}{Ca} - 1\right)^2 - \frac{4fl}{d}}}. \quad (8)$$

Equation (8) has been graphed in Fig. 6 (full lines) for values of $\frac{4fl}{d} = 0, 1, 5, 10, 50$ and 100 assuming f constant for all velocities, or Rn. For example, where $f = 0{\cdot}01$ then $\frac{4fl}{d} = 100$ is equivalent to $\frac{l}{d} = 2{,}500$. The curve for $\frac{4fl}{d} = 0$ is, of course, for the valve alone and is the same as in diagram II of Fig. 5.

The effect of the length of line downstream of the valve is immediately apparent when it is seen in Fig. 6 that with $\frac{4fl}{d} = 100$ the valve can be four-fifths closed and yet the velocity is still 0·83 of the original. Thus the last 20 per cent. of closure must affect 83 per cent. of the cut off.

The area-velocity curve for $\frac{4fl}{d} = 10$ in Fig. 6 has been translated into a closure curve in Fig. 5 for a movement of the valve stem directly with time. The effect of this type of closure on water hammer can be gauged from curve No. 6 in Fig. 3.

As suggested previously a linear closure is preferable, and in Fig. 5 is shown how to obtain such a closure. By using graphs in diagrams I, II and IV of the figure, the curve in diagram III is obtained. This is the relationship of stem movement with time to give a linear closure for a gate valve with a length of line ($\frac{4fl}{d} = 10$) downstream of it.

When the valve is smaller than the line it has greater control over the flow as seen in Fig. 6, where the dotted lines represent valves where $\frac{a_o}{A} = \frac{1}{2}$, i.e. the full-open area of the valve is half the area of the pipe. The effect is to reduce the water-hammer tendency and is a factor in favour of the use of smaller valves. Even though it is the greater head loss through the valve when partially closed that affects this control, such valves when fully open need not be a big drain on the pressure gradient if installed with well-designed diffusers.

REFERENCES

1 "Water-Hammer Studies in Long Pipelines." L. E. Goit. *American Water Works Association Journal*, 1939, vol. 31, p. 1893.

2 "Water-Hammer Control by Proper Valve Installation." E. C. Brisbane. *American Water Works Association Journal* 1939, vol. 31, p. 1904.

3 "A Treatise on Applied Hydraulics." H. Addison. Chapman and Hall Ltd. 1950.

4 "Surge Problems in Pipelines—Oil and Water." S. L. Kerr. A.S.M.E., 1950, vol. 72, p. 667. Discussion by F. M. Van Deventer p. 677.

5 "The Control Valve in Operation." W. H. Kidd and G. A. Philbrick. *Instruments Journal* 1951, vol. 8, p. 1495.

Bailey Bridging Contract. Thos. Storey (Engineers) Ltd. recently obtained a contract to supply nearly £300,000 worth of Bailey bridging to the Swedish Government. Work on this order is now in progress at the Stockport factory.

Earth Moving Equipment. A new series of leaflets has been received from Blaw Knox Limited, viz.: BK-157/2—Hydraulic Bulldozer for David Brown "30 ITD" Crawler Tractor; BK-158/1—Hydraulic Angledozer for David Brown "50 ITD" Crawler Tractor; BK-173/1—Model "A" Mk. II Double Drum Cable Control Unit. Further leaflets deal with the "BK-Fifty" excavator with face shovel attachment (Pub. BK-180) and the "BK-Fifty" excavator with drag shovel attachment (Pub. BK-181).

Ice Prevention at Hydraulic Structures

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PART TWO

THE main air header delivering air from the compressor to the distribution piping is usually placed in an inspection gallery. Galvanized steel pipes with galvanized malleable iron or steel fittings are generally used for the main header and the compressor piping. Fig. 13 shows a portion of the Grand Coulee air supply header located in a gallery of the dam. This 4 in. header is suspended from the ceiling of the gallery by special pipe supports secured to the concrete with cinch anchors. Dresser couplings were used to connect the pipe sections together in the field. This provided the desired flexibility at the dam contraction joints.

Control headers are made either of brass pipe and fittings or of copper tubing with bronze solder joint fittings. They are stationed in an inspection gallery near the supply header. A typical installation of a control header is shown in Fig. 14. The assembly includes an intake valve, a throttle valve to the distribution pipe or pipes, a control valve for each distribution pipe, and a drain valve. A bronze V-type strainer and a pressure gauge complete the assembly. The air flow from the supply header to the control header is controlled by a wedge gate valve and to the distribution piping by a globe valve having a plug-type disc. Control to each individual distribution pipe is effected by means of wedge gate valves. A plug-type disc globe valve is used for draining the control header.

The compressed air required for the operation of the de-icing system is usually supplied by two or more single-stage, air-cooled rotary-type air compressors. Such compressors of the air-cooled type are available for discharge pressures up to 20 lb. per sq. in., and of the water-cooled type for pressures up to 50 lb. per sq. in. Where the required pressure and volume exceed the capacity of rotary machines, reciprocating compressors are used. Although air-cooled, single-stage reciprocating compressors are available for discharge pressures up to 60 lb. per sq. in., the air-cooled type of rotary compressors are preferable for this particular service. This is because of their smooth, vibration-free, air delivery. All rotary compressors used should be of the multicellular sliding vane type, with forced feed lubrication, direct-connected to an electric motor by means of a flexible coupling, all integrally mounted on a common base. The compressor equipment should include an air filter, intake silencer, and automatic unloader on the intake, in addition to a check valve, an automatic

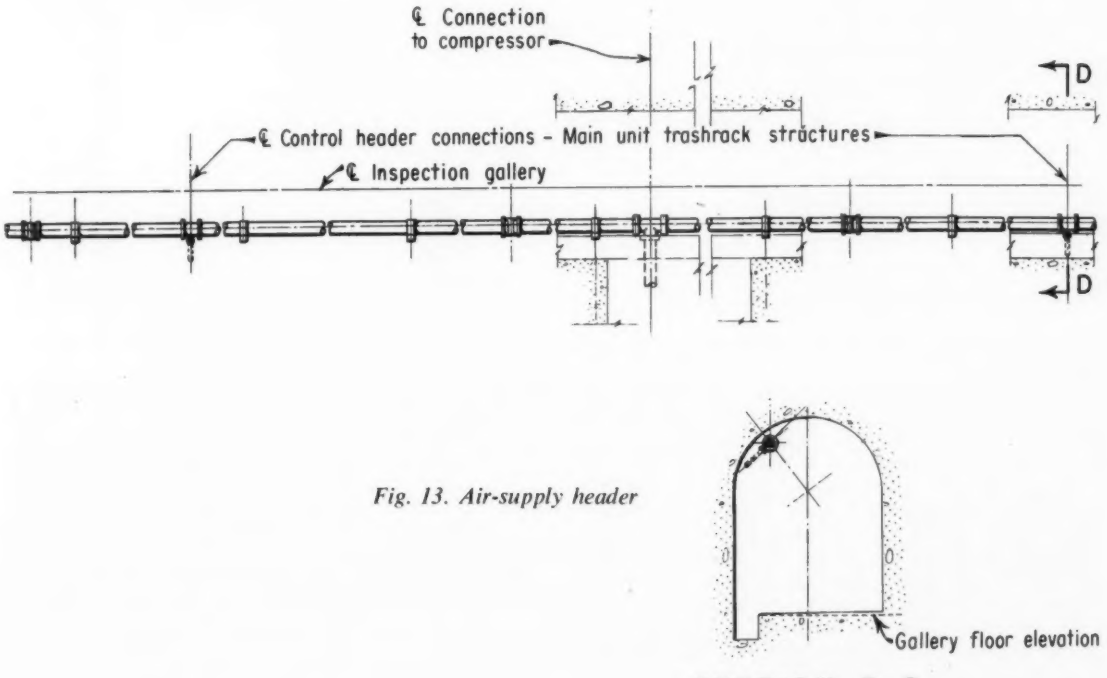


Fig. 13. Air-supply header

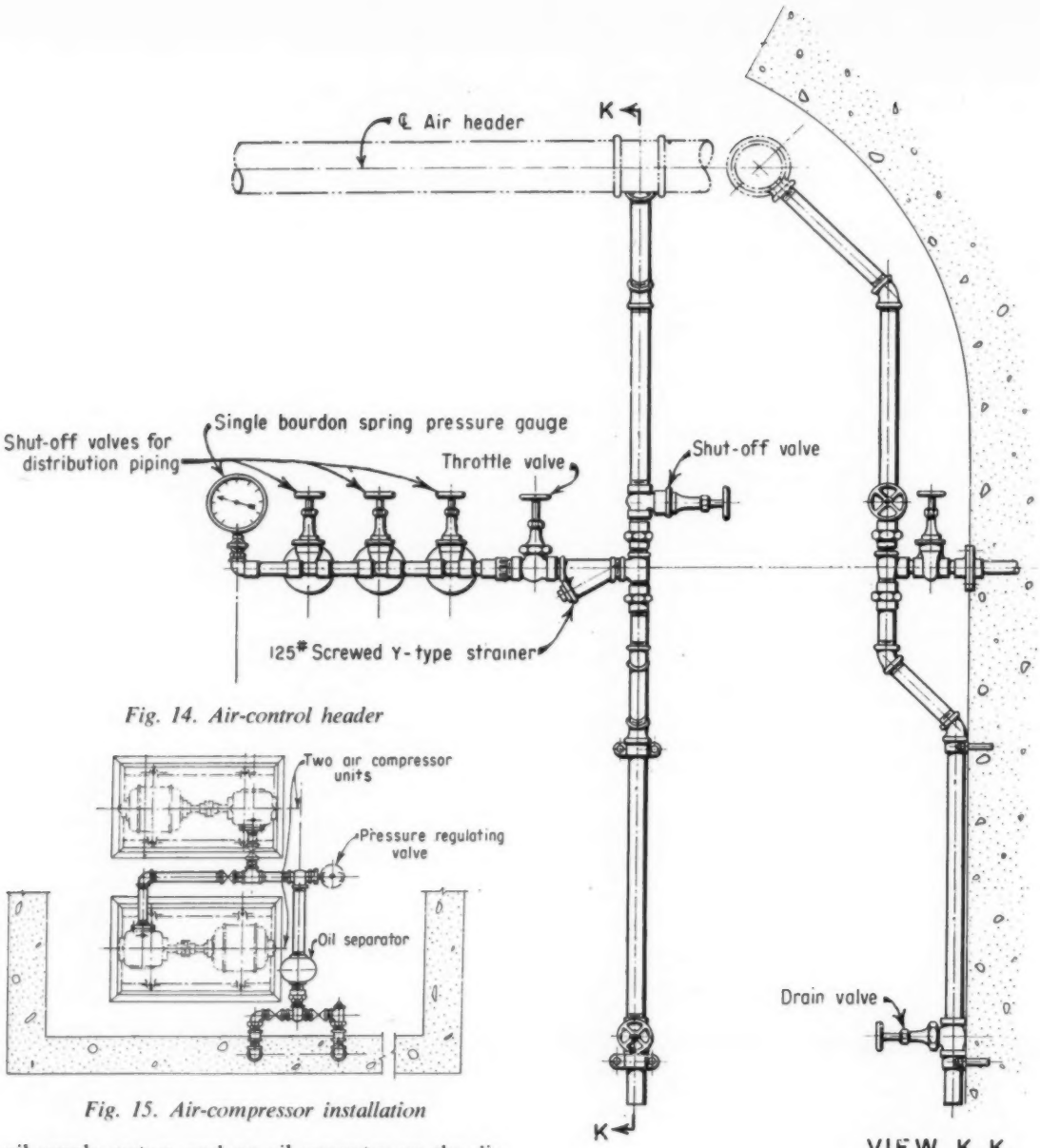


Fig. 14. Air-control header

Fig. 15. Air-compressor installation

oil supply system, and an oil separator on the discharge end.

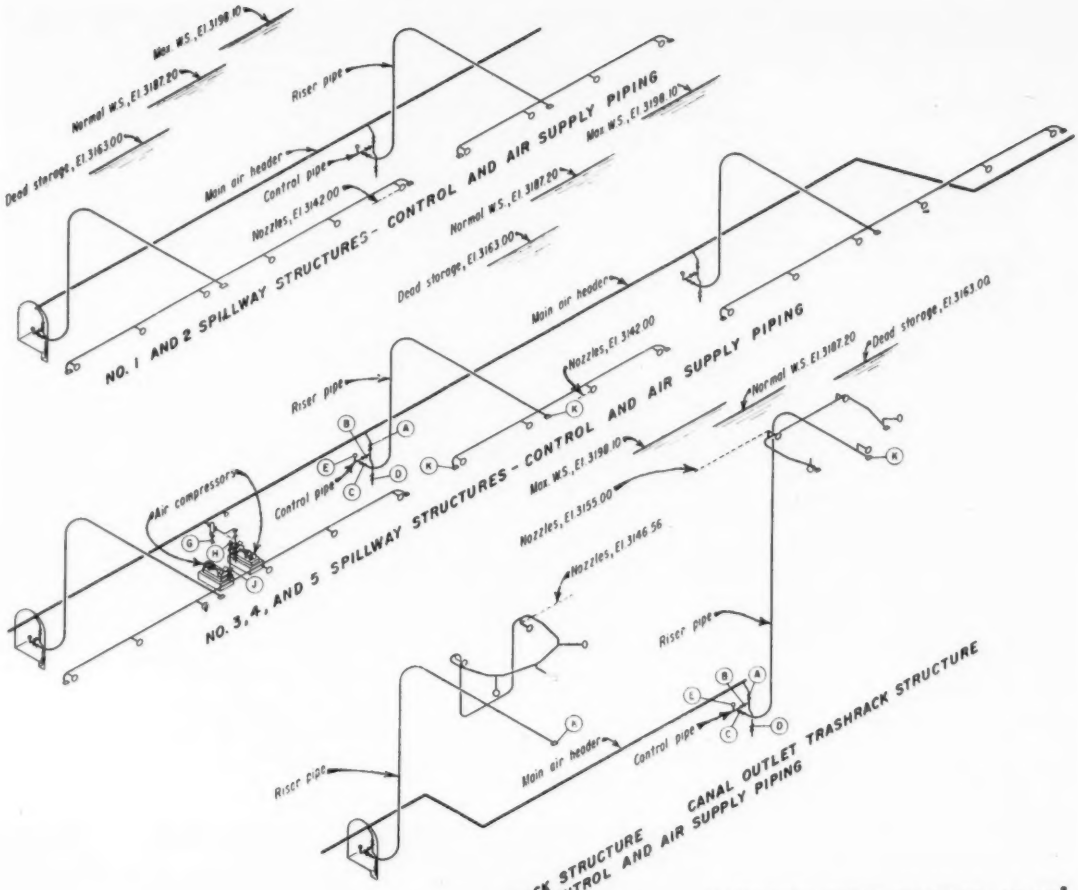
Compressed-air de-icing systems are usually designed to discharge 2 cu. ft. of free air per minute per nozzle at any reservoir level. The required displacement of a compressor is determined from the total number of air nozzles and the volume of free air to be discharged from each. Gauge pressures of compressors should be equivalent to the sum of the maximum head on the nozzle, the differential pressure across the nozzle, and the pressure loss in the piping. A differential pressure across the nozzle of 2 lb. per sq. in. may be assumed in the pressure determination. The pressure loss may be computed from the formula:

$$\Delta p = 0{\cdot}000108\, f l \rho v^2/d$$

where

Δp = pressure loss in lb. per sq. in.
l = length of pipe in ft.
ρ = density of compressed air under flow conditions, in lb. per cu. ft.
v = velocity of flow in ft. per sec.
d = inside diameter of pipe in ft.
f = friction factor.

The friction factor can be determined from appropriate charts after computing the Reynolds number from the formula $\frac{dv\rho}{\mu}$, where μ = absolute viscosity of compressed air, flowing. With the required displacement and pressure rating of the compressor


Max. W.S., El. 3198.10
Normal W.S., El. 3187.20
Dead storage, El. 3163.00
Riser pipe
Main air header
Control pipe
Nozzles, El. 3142.00
NO. 1 AND 2 SPILLWAY STRUCTURES - CONTROL AND AIR SUPPLY PIPING
Air compressors
NO. 3, 4, AND 5 SPILLWAY STRUCTURES - CONTROL AND AIR SUPPLY PIPING
Nozzles, El. 3155.00
Nozzles, El. 3146.56
RIVER OUTLET TRASHRACK STRUCTURE
CANAL OUTLET TRASHRACK STRUCTURE
CONTROL AND AIR SUPPLY PIPING

A - Control pipe "shut-off valve."
B - Control pipe throttle valve.
C - Riser pipe "shut-off" valve.
D - Control pipe drain valve.
E - Control pipe pressure gage.
G - Oil and water separator drain cock.
H - Compressor "shut-off" valve.
J - Compressor discharge drain cock.
K - Cleanout plug.

CALCULATED GAUGE READINGS LB./IN.²

WATER SURFACE ELEVATION	SPILLWAY STRUCTURE NO. 1 AND 5	SPILLWAY STRUCTURE NO. 2 AND 4	SPILLWAY STRUCTURE NO. 3	RIVER OUTLET TRASHRACK STRUCTURE	CANAL OUTLET TRASHRACK STRUCTURE
D.S.L.-3163	11.0	10.9	11.1	9.2	5.9
3165	11.8	11.7	11.9	10.0	6.7
3167	12.6	12.5	12.7	10.7	7.4
3169	13.4	13.3	13.5	11.5	8.2
3171	14.2	14.1	14.3	12.4	9.0
3173	15.0	14.9	15.1	13.2	9.8
3175	15.8	15.7	15.9	14.0	10.5
3177	16.6	16.5	16.7	14.8	11.3
3179	17.4	17.3	17.5	15.6	12.1
3181	18.3	18.2	18.4	16.4	12.9
3183	19.1	19.0	19.2	17.2	13.7
3185	19.9	19.8	20.0	18.1	14.6
N.W.S.-3187.20	20.9	20.8	21.0	19.0	15.4
M.W.S.-3198.10	25.4	25.3	25.5	23.4	20.0

Fig. 16. Operating diagram

determined, it is possible to select the compressor from commercial sizes available. Compressed air is delivered to the air supply header serving as the receiver from which the flow into the distribution pipes is controlled by valves in the control header. Excess air is discharged by means of the automatic unloader. It is desirable to provide compressors in pairs, with electrical controls for alternate operation. The operating time of a compressor will vary up to eight hours, depending on outside air temperature and ice thickness. Fig. 15 shows a typical air compressor and pipe installation. Air compressors are generally installed in inspection galleries containing the air header, or if more space is required a separate chamber adjoining the gallery may be provided in the structure. Air compressors should be installed in accordance with manufacturer's instructions.

Operation of Compressed-Air De-Icing Systems

De-icing systems will vary in complexity according to the structural features to which they apply. The above design fundamentals may be adapted to large structures as at Grand Coulee and Hungry Horse dams, or to smaller structures. To facilitate the operation of de-icing systems, instructions are usually provided for the use of the operating personnel. These operating instructions are illustrated by a diagram showing the arrangement of the piping and nozzles.

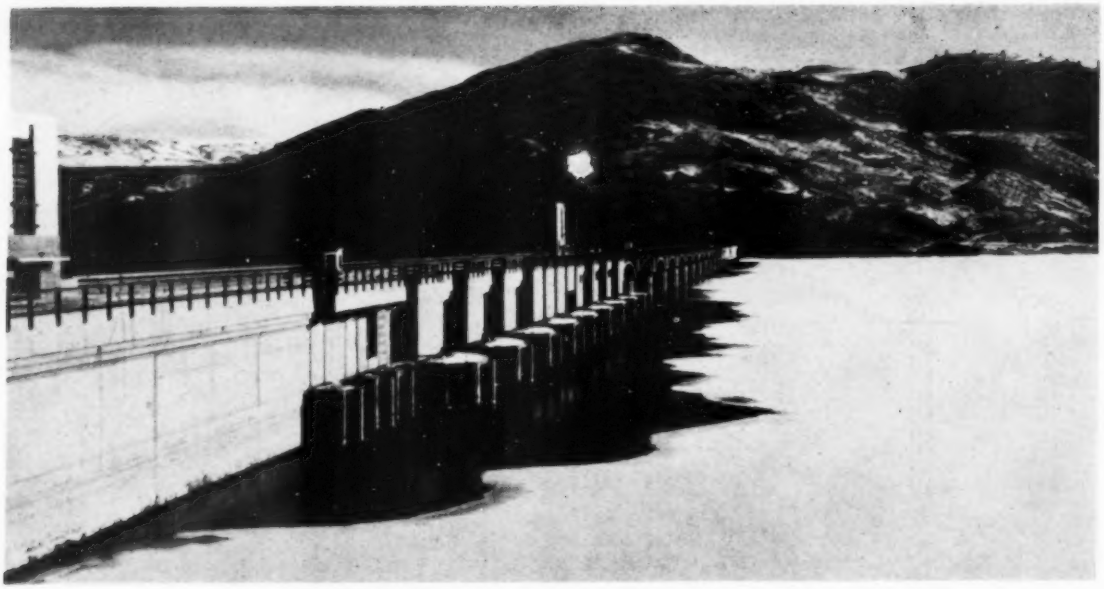


Fig. 17. De-icing system in operation at Grand Coulee dam

A typical operating diagram is shown in Fig. 16. The diagram indicates the operating range of the air nozzles at each water level and gives the location of the various control valves. It is accompanied by a table of calculated gauge readings required in the risers of individual ice-prevention units to control the quantity of air to be discharged (at a rate of 2 cu. ft. of free air per minute per nozzle) at various water surface elevations in the reservoir. The proper gauge pressures should be maintained by regulating the flow of air through the control pipe throttle valve *B*. The operating instructions describe the proper use of the valves at the control header for both the operating cycle and the shut-down cycle of the system. To place a de-icing system in operation the following procedure should be followed:—

1. Close compressor discharge drain cock *J* and open compressor shut-off valve *H*; then start compressor.

2. Close control pipe drain valve *D* and open riser pipe shut-off valve *C*.

3. Keep control pipe throttle valve *B* wide open until all water has been cleared from the riser pipes and air is flowing freely. During this clearing operation the control pipe drain valve *D* should be slightly open to permit the escape of any water running back from the riser pipes.

4. After the riser pipes have been cleared of water, regulate the control pipe throttle valve *B* so that the readings of pressure gauge *E* conform to the tabular values.

5. Accumulated moisture should be removed from the piping periodically during the operation of the system by opening drain valve *D* and drain cocks *G* and *J*.

Fig. 18. Air bubbles rising to reservoir surface at Grand Coulee dam

Fig. 19. De-icing system in operation at Black Canyon dam

6. As the second compressor is a standby unit for alternate and emergency operation, its shut-off valve *H* should be kept closed when not in operation.

When the de-icing system is not in operation, the valves should be in the following position:—

a. The riser pipe shut-off valve *C* should be closed to prevent water from entering the main air header.

b. The control pipe valves *A*, *B* and *D* should be open to permit free drainage of the main air header.

c. The compressor shut-off valve *H* should be closed and the compressor discharge drain cock *J* should be open.

Air compressors should be operated, tested, and maintained in accordance with the manufacturer's recommendations. The pressure relief valve in the compressor will prevent the development of excessive pressures in the main air header by discharging excess air into the atmosphere.

Operating experience with the compressed-air de-icing systems has proved that they fulfil the requirements by effectively preventing or removing ice formation from critical areas of hydraulic equipment and structures. Fig. 17 shows the upstream face of Grand Coulee Dam during a time when the reservoir was covered with a 6 in. thickness of ice topped by a blanket of snow. This photograph was taken when the compressed-air de-icing system for the trashracks of the penstock and outlet works intakes was in full operation. The operating efficiency of the de-icing system is indicated by the ice-free area in front of the trashracks. A close-up of the agitation produced by the rising air bubbles is shown in Fig. 18, and Fig. 19 shows the effect of the de-icing system installed at Black Canyon Dam.

Aluminium Production

In a report for the year ending December 31, 1953. Nathanael V. Davis, President of Aluminium Limited, stated recently that $129 million had been spent in implementing the company's plant expansion programme; about one-third of the newly acquired assets came into operation during the year, and the remainder, chiefly the Kemano-Kitimat aluminium project in British Columbia, would be in operation in the summer of 1954. Sales of aluminium in all forms by consolidated subsidiaries were 597,779 tons, a new high level which exceeded the amount produced and sold in any previous year in the commercial history of the metal.

Referring to the Kitimat project, Mr. Davis stated that the task in British Columbia had been an arduous one, and had resulted in expenditures in excess of original estimates, largely as a result of inflationary factors and the element of remoteness involved in a project far from populated centres. With operations soon to begin at Kitimat, the essential base for a large production had been established, and the new site, with its potential of rapid and low-cost expansion, was expected to be a sound and economic source of future production.

No expansion at Kitimat beyond the first stage of 91,500 tons, he added, had yet been authorised, but in order to be in a position to undertake further construction of additional capacity of equal size without delay, a decision had been made in 1953 to prepare the plant site and groundworks for such expansion while the earth-moving equipment was still on the location. This work had now been completed. The ultimate planned capacity of the British Columbia project, he went on to say, was 550,000 tons of aluminium per annum, supported by an installed hydro-electric generating capacity of 2,240,000 h.p.

Tunnelling Operations on the Alcan Project

Following our description of the Kitimat project, a correspondent submits some interesting data comparing the drilling results obtained with light and heavy equipment.

BECAUSE the respective merits of light-weight European-type rock drills and the heavy two-man rock drill favoured in the U.S.A. are a subject for debate wherever mining and tunnelling is carried out, the Alcan project in British Columbia has proved of singular interest in this field, as both types of equipment were used on the tunnelling operations.

In the past five or six years the light-weight equipment has made noticeable inroads into the markets formerly held by the older heavy-weight equipment. This has been most marked in Europe where virtually all tunnelling schemes, including the various hydro-electric projects in Scotland, are being carried out with light-weight drills. In mining operations, particularly in Canada and Australia, the light-weight drill has been readily accepted. In Australia, the one-man light-weight drills have been credited, in some cases, with being the main factor in reducing costs at a time when some of the Western Australian gold mines were threatened with having to close down.

As the Alcan project has been described in detail in WATER POWER (March and April), it is not necessary to go further into this scheme other than to discuss certain features which provide the background for this article. The real work of tunnelling began on March 6, 1952, and finished with the break-through of the tunnel on December 3, 1953. Work was carried out from four main headings, one from Kemano (downstream end), two from Horetzky (central adit), and one from West Tahtsa (upstream end).

The contractor for the project was the Morrison-Knudsen Company of Canada Ltd. Even with four headings in operation, the time limit was a very close one and a strict schedule had to be organised for each of the four working faces. The general procedure for tunnel driving was similar at all four points.

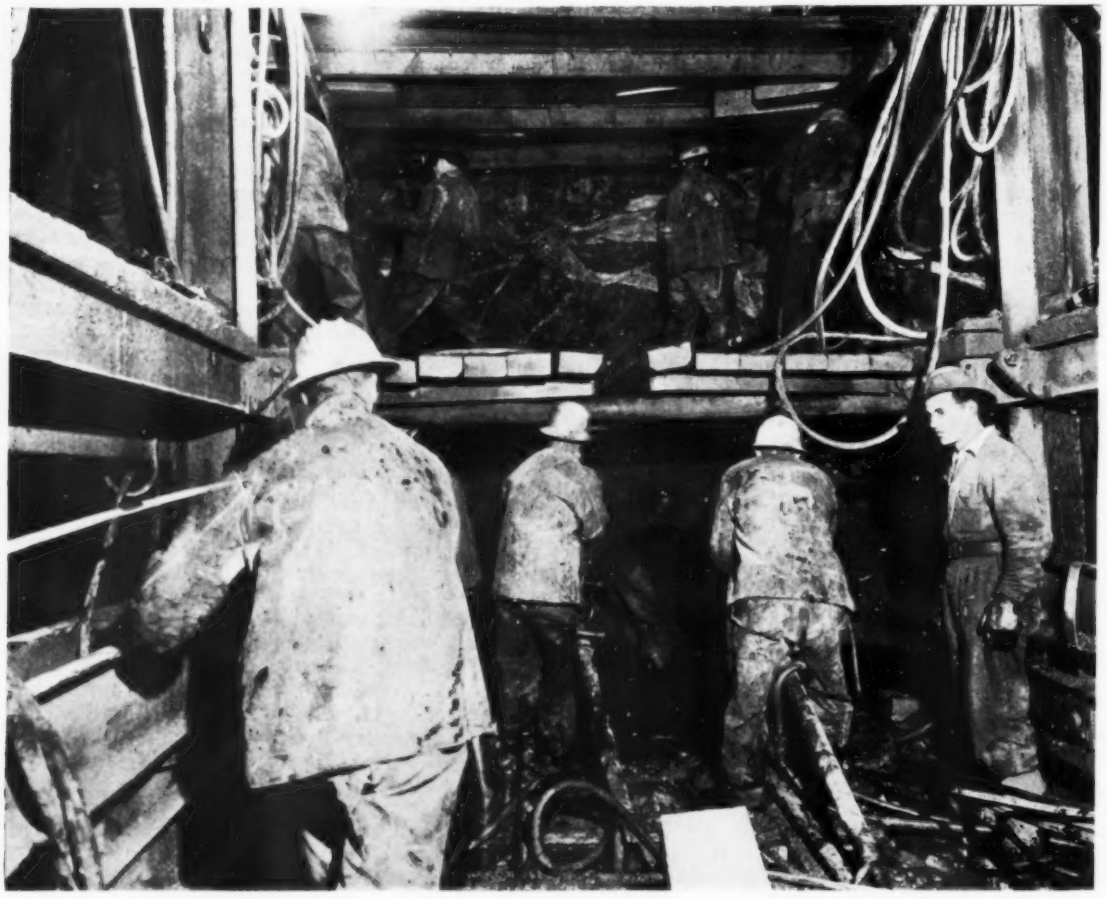


Fig. 1. Tahtsa heading, drilling a round with the light air-leg equipment

Fig. 2. Enlarging the valve chamber with Atlas-Copco drills and Coromant steels

Conway muckers of 100 h.p. each were used to load the muck, and combination battery and electric trolley locomotive-drawn trains of 6 cu. yard (with built-up sides for 7 cu. yard) mine cars were employed for haulage purposes over 36 in. gauge 60 lb. rail track. Drilling in each case was done from a built-up steel jumbo travelling on rails and carrying a car changer or "cherry picker," to feed the empty cars ahead of the train to the mucking machine. At all headings five cars was considered a normal train load. The work was organised to run on a six-day basis, a list of the mucking and drilling equipment used on the various headings being given in Table I.

TABLE I

Heading	Rock Drills	Mucking Equipt.	Steels	Bits
Kemano -	Ingersoll-Rand DA 35	No. 100 Conway loaders	1¼ in. rods	2 in. Carset tungsten carbide
Kemano-Horetzky -	,,	,,	,,	,,
Horetzky West Tahtsa -	,,	,,	,,	,,
West Tahtsa -	Atlas-Copco RH 656	,,	⅞ in. Coromant Steels	Tungsten-carbide bit inserts

Rock Encountered

The type of rock encountered varied from coarse-grained granodiorite and quartz diorite at the Kemano end to granite shot with trap dikes at the midpoint, Horetzky, and to a green stone and metamorphic complex at the West Tahtsa end. This variation in rock structure, which determined the difficulties encountered, is amply indicated in Table II, which shows the number of steel segment sets erected in the various headings, up to September 30, 1953.

From these figures certain facts emerge. The green stone and metamorphic complex at the West Tahtsa heading resulted in tunnelling difficulties that were

TABLE II

	West Tahtsa	Horetzky West Tahtsa	Horetzky Kemano	Kemano
Dates work started -	6.3.52	1.4.52	21.4.52	16.3.52
Length driven to Sept. 30, 1953 - ft.	12,118	11,680	11,332	14,410
No. of steel sets used to Sept. 30, 1953 - ft.	817	321	371	47

the worst encountered on the whole tunnelling project. These difficulties necessitated the erection of more steel segment sets at West Tahtsa than at the other three headings combined. Valuable drilling and mucking time was thus sacrificed to the erection of the steel segment sets. Nevertheless, as indicated in the table, the total length driven in the West Tahtsa heading was second only to the Kemano heading, where the best rock, granodiorite and quartz diorite, was encountered. It should be remembered that each heading was working to the same rigid time schedule, which stipulated that the tunnel had to be completed by the end of 1953.

Tunnelling Records

Great interest has been shown in the records established for tunnel driving on this project. No less than five new world records were established while the tunnel was being driven. The number of factors involved in the breaking of these records were many. Rock conditions, efficiency of machinery and probably, most important of all, the human element, contributed to the records that were achieved. The records given in Table III were for tunnel advance in six days.

Drilling represented only about 18 per cent. of the total time per round. Obviously other factors, such as mucking, are of particular importance in tunnelling progress. The following figures taken from a report on the Atlas-Copco record week at West Tahtsa, illustrate the time taken in carrying out some of these operations. In an 8 hr. working shift drilling took 1 hr. 26 min., and mucking 2 hr. 13 min. The laying of new track took 15 min., the loading and blasting process, 33 min., ventilation after blasting, 30 min., and the setting up of the equipment, 24 min. Miscellaneous operations occupied 17 min.

However, since the same mucking equipment was used in all headings, and assuming the human element can be equated in relation to the operations mentioned, the only serious difficulty in a comparison of the two methods of drilling is the rock encountered, as indicated by the steel segment sets installed.

Drilling Comparison

From information already published on the Alcan project, it is now possible to draw some comparisons

TABLE III

Footage	Date	Heading	Equipment
248	Sept. 28, 1952	Kemano	Heavy
261	Nov. 1, 1952	Kemano	Heavy
272	Nov. 2, 1952	West Tahtsa	Light
274	Nov. 29, 1952	Horetzky	Heavy
282	Feb. 21, 1953	Horetzky-Kemano	Heavy

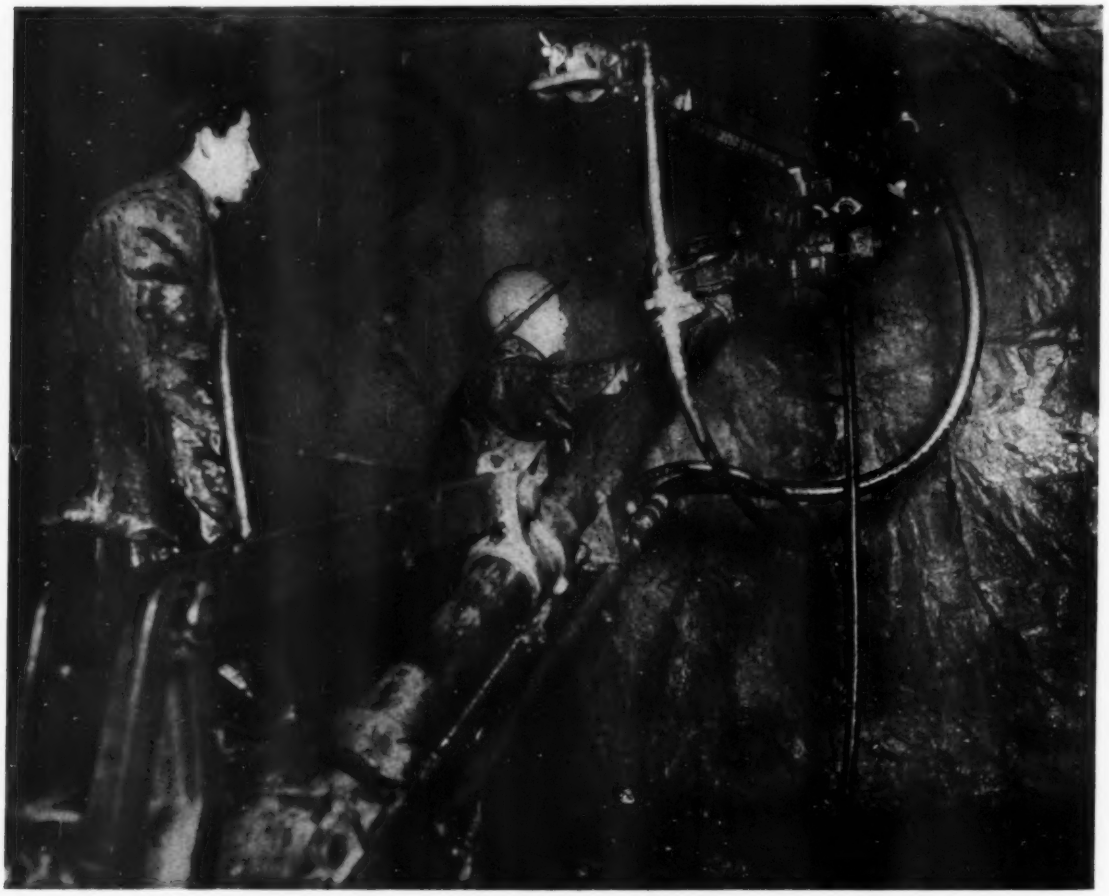


Fig. 3. Heavy-type drilling rig on upper deck of jumbo, Power Tunnel No. 1

between the two drilling methods used, in order to evaluate efficiency and speed. *Mining and Engineering*, November 1952 published the average footages and other relevant details (Table IV) before that date.

TABLE IV

	Light-weight drills	Heavy-weight drills
Number of rock drills	16	15
Number of drills and helpers	21	34
Drilling time in minutes	105	105
Footage per shift	12	12

When this table appeared, the light-weight equipment was being used in a heading of 45 sq. yards section, and the heavy equipment in a heading of 48 sq. yards. The table thus shows that 2·14 cu. yards of rock was excavated per man using the light drills, compared to 1·71 cu. yards per man using the heavy drills.

In October 1953, the *Bulletin of the Canadian Institute of Mining and Metallurgy* published a paper, presented at their Annual General Meeting, by F. J. Matthias and C. W. Abrahamson, entitled "Tunnel and Powerhouse Excavation at Kemano B.C. and Alcan Hydro Power." This article gave figures for the record week set by the heavy drills. This record (Table V) is compared to the earlier record held by the light drills.

TABLE V

Heading	Light Drills West Tahtsa	Heavy Drills Horetzky-Kemano
Type of drill	RH 656	DA 35
Date of record week ending	Nov. 22, 1952	Feb. 21, 1953
Record footage in six-day week	272	282
Average daily advance in feet	45·3	47·0
Number of rock drills	16	15
Number of miners and helpers	22	31
Number of holes per round	92	102
Footage drilled per round	1100	1148
Average depth of hole in feet	12·0	11·25
Drilling time per round in minutes	86	95
Rate of penetration per rock drill (in. per min.)	9·60	9·64
Rate of penetration per man (in. per min.)	6·98	4·67

Drilling speed, as shown by penetration per rock drill, is virtually the same for both drills, but when calculated on the basis of man-shifts, the light drills have a 49·5 per cent. advantage over the heavy drifters.

Fig. 4. Further view of Ingersoll-Rand drills at work in No. 1 Power Tunnel, 2,600 ft. level

The reduction in holes drilled at West Tahtsa, presumably due to rock conditions, probably accounted for the 10 per cent. saving in time spent drilling. It should be pointed out, however, that the rock, a metamorphic complex, although not difficult to penetrate, requires the erection of segment sets. Also the chisel bits used on the light drills are much more efficient when used in hard rock. This was not demonstrable because of the soft rock that was usually encountered in the West Tahtsa heading.

In an article, "Hard Hats versus the Wilderness on the Alcan Project," published in the December 1953 issue of *Western Construction*, the figures reproduced in Table VI appeared from information provided by C. W. Abrahamson, Assistant Resident Engineer for "Alcan."

TABLE VI

	Heavy Drills	Light Drills
Heading	Kemano	West Tahtsa
Type of drill	DA 35	RH 656
Make	Ingersoll-Rand	Atlas-Copco
Number of rock drills	15	21
Bits steel	Carset detachable bits	Coromant integral rods
Footage per bit	240	600
Number of regrinds	8-10	8-10
Drilling time in minutes	100	87
Typical shift crew	40	31
Pounds of powder per cu. yard	5·41	3·20

The lighter equipment shows marked economies in this table since the Coromants apparently outdrilled Carset bits by more than two to one. However, some allowances undoubtedly should be made for rock conditions. Powder consumption, partially due, possibly, to the small holes drilled because of the smaller diameter of Coromant steels which were used with the light drills, was 41 per cent. lower at the West Tahtsa heading. Opinion is definitely divided regarding the merits of the small-diameter steels used with light-weight drills. However, experience on the Alcan project would seem to show that the light-weight steels and small-diameter holes are more than adequate for any type of tunnelling work.

As 22½ per cent. less men were employed at West Tahtsa per heading a considerable saving resulted in auxiliary services needed to supply the camp personnel; less accommodation, kitchen staff and supplies were needed and there was consequently some saving in the cost of running the West Tahtsa camp.

Before the completion of the tunnel work, it was obvious that concentration on maintaining speed, which was borne out by the number of world records established, made it impracticable to consider any drastic changes in the method or equipment. However, now that the tunnel has been completed, a survey of all available information shows that while the record week of advance was achieved by the heavy equipment, the obvious savings in costs achieved by the light drills—covering initial outlay, labour and spares—are not to be gainsaid.

In various parts of the world today, many of the great civil-engineering projects, hydro-electric schemes in particular, are being financed by public money. It is not unreasonable therefore to assume that the economies secured with light-weight drilling equipment will be of definite interest to consultant and contractor alike.

Allis-Chalmers, Great Britain Ltd. The formation of Allis-Chalmers, Great Britain, Ltd., a wholly-owned subsidiary, was announced recently by W. A. Roberts, president of Allis-Chalmers Manufacturing Company, Milwaukee, who stated that his company was broadening its operations in England from a strictly sales activity to include facilities for manufacturing and export. The firm's British manufacturing operations are to be concentrated at Essendine, England, where model "B" wheel tractors, "All-Crop" harvesters and "Rotobalers" are manufactured. In addition, the plant recently began to manufacture mechanisms for "Low-Head" screens sold by the general machinery division in England and Europe. The subsidiary will handle all Allis-Chalmers operations in the British Isles and in the various export markets served from the United Kingdom. Mr. E. J. Mercer is the general manager of the new company.

New Aluminium Casting Alloy. British patent rights covering the manufacture of castings in an aluminium alloy known as Frontier 40-E, held by the Frontier Bronze Corporation of Niagara Falls, U.S.A., have been acquired by Daralum Castings Limited, of Darlington. Arrangements have been made for the manufacture of the ingot by John E. Moore Limited, of Yeadon, Yorks., and it is the intention to grant sub-licences to approved foundries in due course.

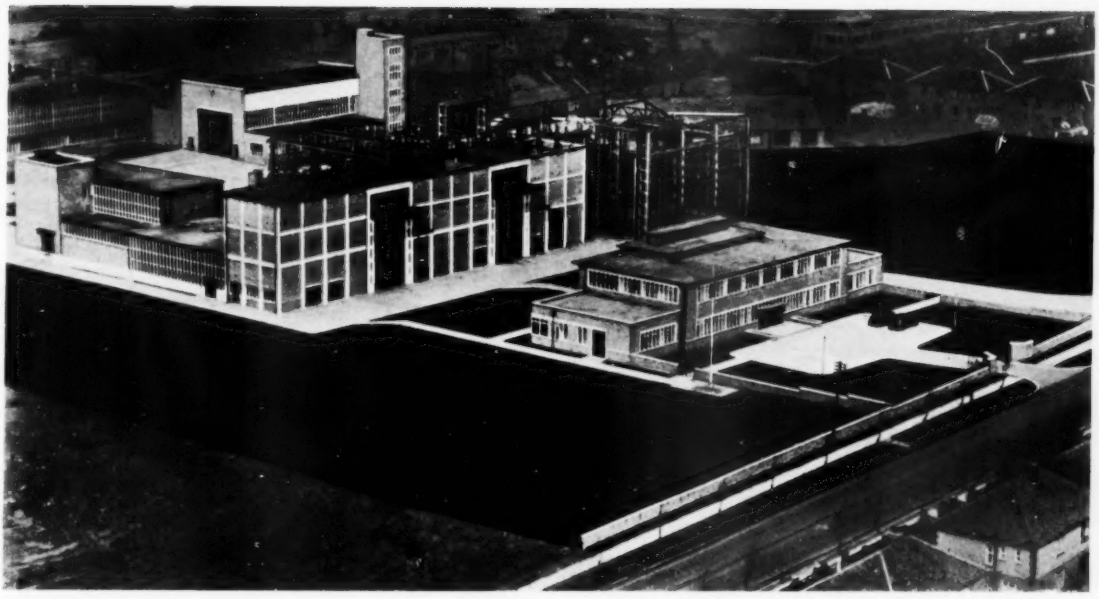
Alloy 40-E is the result of considerable research and development and its outstanding feature is its property of age hardening at room temperature to give minimum routine mechanical properties of 13 tons per sq. in. yield point; 16 tons per sq. in. u.t.s.; 5 per cent. elongation; and 75 Brinell (500/10). This natural ageing ability renders the alloy suitable for welding and brazing, as castings re-age and therefore regain their mechanical properties after the heating applied during these processes.

It is claimed that 40-E has excellent corrosion and stress corrosion resistances which have been shown to be equal to that of the Al-Si-Mg alloys. Its machinability is said to be superior to that of most other aluminium casting alloys.

Consulting Partnership. Mackness & Shipley, Consulting Engineers, of Parliament Mansions, Abbey Orchard Street, London, S.W.1, inform us that they have taken Mr. W. M. Bennett, A.M.I.E.E., into partnership.

Professor L. Escande. We are pleased to record that Professor L. Escande, Director of l'École Nationale Supérieure d'Électrotechnique et d'Hydraulique, Toulouse, who has frequently contributed to our columns, notably on surge-tank design and on hydraulic research, has received the distinction of election as a Member of l'Académie des Sciences de Paris.

Boving & Co. Ltd. Mr. O. Thott, M.I.Mech.E., who since 1931 has filled the position of managing director of Boving & Co. Ltd., has become vice-chairman of the company, and has been succeeded as managing director by Mr. D. A. Akins, B.E., A.M.I.C.E., Mem.A.S.M.E., who has been with the firm since 1934, and a director since the beginning of last year.



Reyrolle High-Power Short-Circuit Research Station

In 1929 A. Reyrolle & Co. Ltd. commissioned the first regular short-circuit testing station for switchgear in Great Britain. This station was extended in 1934, but advances since then in switchgear design have called for testing plant of much greater capacity. To meet this need a new short-circuit testing and research station has just been opened in which it is possible to make full-scale three-phase, single-phase or unit tests which will prove almost any gear likely to be built in the foreseeable future.

Although three-phase short-circuits of very high output can be obtained up to 275 kV, the prime object of the station has been to provide the greatest possible outputs single phase. These high single-phase outputs are achieved by four main features:

(i) By taking advantage of the fact that in single-phase circuits with all transformers connected in parallel, the lowest plant reactance can be obtained.

(ii) By arranging the generators in so-called U connection. This is a single-phase arrangement using all windings in such a way that the reactance is reduced and the single-phase output of each generator is increased by at least 33⅓ per cent.

(iii) By providing over-exciter sets which ensure a high recovery voltage, and correspondingly high currents during test. These enable the maximum benefit to be gained from the U connection.

(iv) By arranging to apply the short-circuit at any selected point of the voltage wave, thus exercising complete control over the degree of asymmetry and making it possible for symmetrical tests to be made immediately after the start of the short-circuit and before the subtransient component of the current has died away.

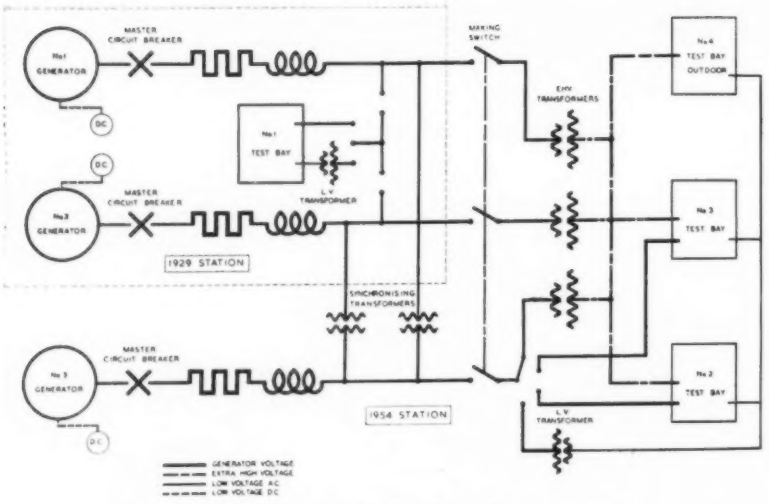
Three short-circuit generators, together with their associated over-exciter sets, provide the source of power. Each machine has its own master circuit breaker, current-limiting reactors, resistors, and making-switch, and normally feeds its own group of E.H.V. transformers.

The short-circuit generators are normally paralleled on the E.H.V. side of the transformers to avoid the very large currents which might otherwise flow in the event of a generator fault. This necessitates the provision of an auxiliary synchronising tie to hold the machines in parallel prior to the application of the short-circuit. For this purpose two single-phase 500 kVA transformers are used.

The maximum output of the station occurs, quite naturally, with full excitation or over-excitation. This means that it will be obtained at certain fixed voltages. These include the voltages in use in Great Britain and

Voltage range	Three-phase or Single-phase	Output
Up to 22 kV	Three-phase	2,000 MVA
33 kV to 275 kV	Three-phase	1,500/2,500 MVA
66 kV to 380 kV	Single-phase	3,200 MVA* (with $\frac{1{\cdot}5\,E}{\sqrt{3}}$ recovery voltage) 4,800 MVA* (with $\frac{E}{\sqrt{3}}$ recovery voltage)

*Equivalent three-phase output



Main circuit diagram of the Reyrolle test station

also some voltages used abroad. In each range the output is substantially the same at all these voltages. The position is summarised in the accompanying Table.

No. 3 generator, supplied by C. A. Parsons & Co. Ltd., has a frame size of 60 MVA, a reactance of 4 per cent., and is driven at 3,000 r.p.m. by a 1,200 h.p. induction motor. The over-exciter set for this generator is separately driven and delivers 1,600 A at 625 V—an output that can rise to 3,000 A during alternator short-circuit. A 12½ ton flywheel is provided to improve the short-circuit characteristics.

The other two machines previously supplied by C. A. Parsons & Co. Ltd. are similar in size and appearance, but their windings are arranged differently and their output is slightly lower. All three generators are arranged with two windings per phase, which can be connected in series or parallel, star or delta, to give the four basic three-phase voltages of 6·35, 11, 12·7 and 22 kV. Intermediate voltages are arranged by excitation control. The U-connection is also available to give 19·1 kV with normal excitation and 22 kV with over-excitation.

The master circuit-breakers are a development of the standard Reyrolle class R switchgear, and are fully phase-separated. They can break the full output of the generators at any voltage. This involves currents of 50 kA at 22 kV, and 80 kA at 11 kV.

Current is controlled by reactors and resistors. The latter are used mainly to adjust the power factor. The reactors are arranged in two groups. Those for controlling the short-circuit current consist of air-cored coils in stacks of three. They are provided with tapping points and self-locking isolator links permit rapid circuit changing. The reactors for controlling currents in the load-current range are three-phase iron-cored units, giving a range of 5-250 A at 11 kV.

Normally, short-circuits are applied through the making-switches, which consist of three 3-phase units (one for each generator). These switches close at any selected point of the voltage wave. They have therefore been designed to precision limits. To reduce arcing before make the contacts are enclosed in compressed air at 150 lb. per sq. in. and the speed of make is high. Operation is by pneumatically charged springs. All nine poles can be ganged mechanically with clutches between groups of three. They are capable of making currents up to over 150 kA peak. Control is exercised through a thyratron, triggered from a 440 V supply in synchronism with the main sets and tied in with the main test sequence through the master controller.

At the 1954 station there are two indoor test bays, and one outdoor. The indoor bays are large enough to take a three-phase, 132 kV circuit breaker, while the outdoor bay can take a three-phase 380 kV circuit breaker.

The E.H.V. transformer bank comprises 12 single-phase Parsons shell-type 11/38 kV transformers, and three single-phase Parsons shell-type 11/152 kV transformers. The reactances are as follows: 152 kV transformers, 3 per cent. on a 50 MVA frame size; 38 kV transformers, 3·3 per cent. on a 12·5 MVA frame size. The 152 kV transformers are provided with two primary windings, for 22 or 11 kV, and four secondary windings, each 38 kV, which can be connected in four series-parallel arrangements to give 38, 76, 114 and 152 kV. This method of connection keeps the transformer output almost constant, irrespective of the voltage. The different arrangements are selected by oil-immersed switches.

Control is exercised from a central building, which also accommodates recording equipment, observation rooms, offices, and the like. One of the observation rooms is also available as a lecture theatre.

Extensive facilities are provided to deal with the many photographic techniques in use.

Open-Bowl Scrapers

Three new models have been added to the range of Onions open-bowl scrapers, and are being exhibited at the B.I.F. by Jack Olding & Co. Ltd. The first model, the 12-16, was put on the market two years ago, and as a result of its favourable reception it was decided to produce three further sizes—the 3-4, 8-11 and 15-21. In recent years tractor manufacturers have raised the drawbar pull of their machines for scraper operation, and many tractors are now capable of operating scrapers of somewhat larger capacity than those originally used. The new Onions scrapers retain many of the well-proved features of the earlier overhead-beam type, and in addition have the advantage of a lower centre of gravity; this feature, coupled with rear wheels set to the full width of the bowl, is claimed to provide improved stability when operating over rough or sliding ground. Also the apron opening has been raised to permit loads to be ejected in a shorter time and with greater ease. Ejection is by the central thrust tailgate—a system which has proved to be very successful in service, as it provides easy control over dumping and minimises

both wear and abrasion on the guide rollers.

Model 3-4 is of particular importance in view of the increasing number of small industrial tractors which are being used for minor earth-moving projects where the use of a larger machine can scarcely be justified. This model, incidentally, has recently been approved by the Ford Motor Company for use with the Fordson Major Mk III.

"Speed-Finn" High-Speed Drill

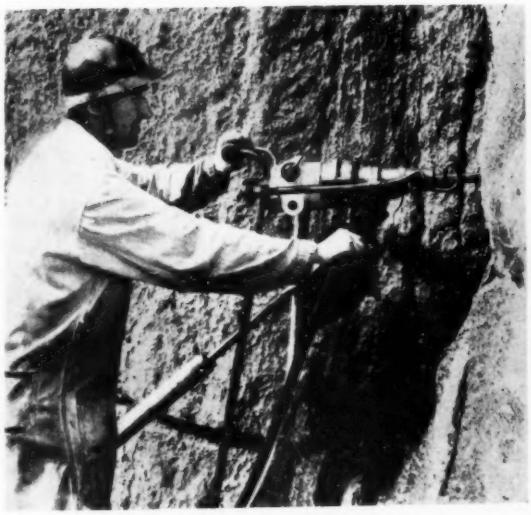


Fig. 1. "Speed-Finn" drill in use with airleg

A high-speed drill for which excellent performance is claimed is the "Speed-Finn" manufactured by Tampella Engineering Works, Tammerfors, Finland. It is designed for use with tungsten-carbide-tipped drill rods, and is available in two sizes—the T5 (Fig. 1), which is a small machine, weighing 25 lb., for light miscellaneous drilling jobs, and the T10 (Fig. 2), which is an all-purpose powerful machine weighing 44 lb., and measuring about 20 in. overall. The cylinder diameter of the latter machine is 100 mm. (4 in.) and the piston, which has a stroke of 32 mm. (1¼ in.), delivers 3,500 blows per minute. The machine incorporates automatic rotation and alternative flushing by air or water.

Support for the drill can be provided by a normal airleg, as seen in Fig. 1, but Tampella Engineering Works also supply a universal feed device which is shown in use in Fig. 2. This consists of a pneumatic cylinder, which is bolted to the rear of the drill. A hole 2-4 in. deep is drilled in the face near the point where the blasting hole is to be cut, to receive an anchor lever, and a chain secured to this anchor lever is looped by a convenient link over a hook on the pneumatic cylinder when the drill has been placed in the drilling position. The weight of the appliance is about 11 lb.

Two advantages are claimed for this device. In the first place it completely absorbs the recoil of the machine, so that the operator is relieved entirely of vibration and resultant fatigue. Secondly, the device can be used for drilling in any position; thus it can be applied not only for the horizontal or oblique drilling for which an airleg is suitable, but it can

Fig. 2. "Speed-Finn" drill cutting a vertical hole with the aid of the universal feed device

equally well be applied to downward and vertical drilling, as depicted in Fig. 2.

In the accompanying Table details are given of recent tests on a T10 machine furnished with a normal airleg and using single-chisel-type tungsten-carbide-tipped drill steels in a grey granite containing 60-70 per cent. quartz.

Test and Date	Steel Length	Bit Dia.	Air Pressure	Rate of Advance	Air Consumption
Wet Drilling	ft.	in.	lb./sq.in.	in./min.	cu.ft./min.
	2·65	1·339	62	16½	74·2
	5·25	1·3	62	16½	77·8
15.1.54	7·9	1·26	64	15½	77·8
	7·9	1·26	64	16½	77·8
	10·5	1·221	65	14⅝	81·3
Dry drilling					
	2·65	1·339	82	30⅝	109
14.10.53	2·65	1·339	74·6	24⅞	103
	2·65	1·339	72	18⅞	88·5
	2·65	1·339	64	16½	83

Plastic Conduit

The General Electric Co. Ltd., Witton, Birmingham, has perfected a conduit tube made in P.V.C. (polyvinyl chloride) which can be used for electrical installations, or parts of installations, where severe corrosive conditions exist. It is resistant to the majority of acids, unaffected by moisture or damp, oil or grease, and may be buried in the ground, lime, mortar or cement.

It is lighter than steel or aluminium, is non-inflammable, does not split or fracture, and remains rigid in temperatures up to 140°F.

The constituents of the tube are so balanced as to enable it to be manipulated and handled like steel conduit so that the wireman does not have to learn a new technique. Bends and sets can be made cold in the normal type of bending machine used by electricians and no heating is required, although a bending block is not recommended as this would produce flattening. Threads can be cut with ordinary screwing tackle and no special dies need be kept for the purpose. Details as to the use of conduit fittings can be obtained from the General Electric Co. Ltd.

New Loader-Dozer Equipment

Fig. 1. Anthony-Hamilton loader-dozer discharging to lorry

International Harvester Company of Great Britain Limited have introduced a new type of loader for use with their BTD-6 and BT-6 tractors, made at their Doncaster works. The loader is being made by Anthony Hoists Limited and will be marketed at home and overseas by the International Harvester sales organisation. The equipment is mounted at the rear pivot points of the crawler tractor and consists principally of a combination bucket and chute fixed to an A-frame. The shovel is loaded by the forward movements of the tractor, after which hydraulic rams lift the bucket over the head of the operator while he is moving back to his unloading point. At the end of this reverse movement the bucket is tripped and discharges the load at the rear. Hydraulic power returns the shovel to the working position as the tractor moves forward to reload.

Fig. 2. The machine loading from a stockpile

The bucket has a struck capacity of $\frac{3}{4}$ cu. yard and is noteworthy in that the width, $66\frac{1}{4}$ in., is greater than the tractor itself, so that it can make its own road, if necessary, through a pile of material. Being crawler mounted, pivot turns are possible, and the combination of these features means that the equipment can be manoeuvred in many confined places which are inaccessible to wheel tractors. Similarly, the crawler mounting enables the outfit to travel with certainty in rough terrain and over steep slopes.

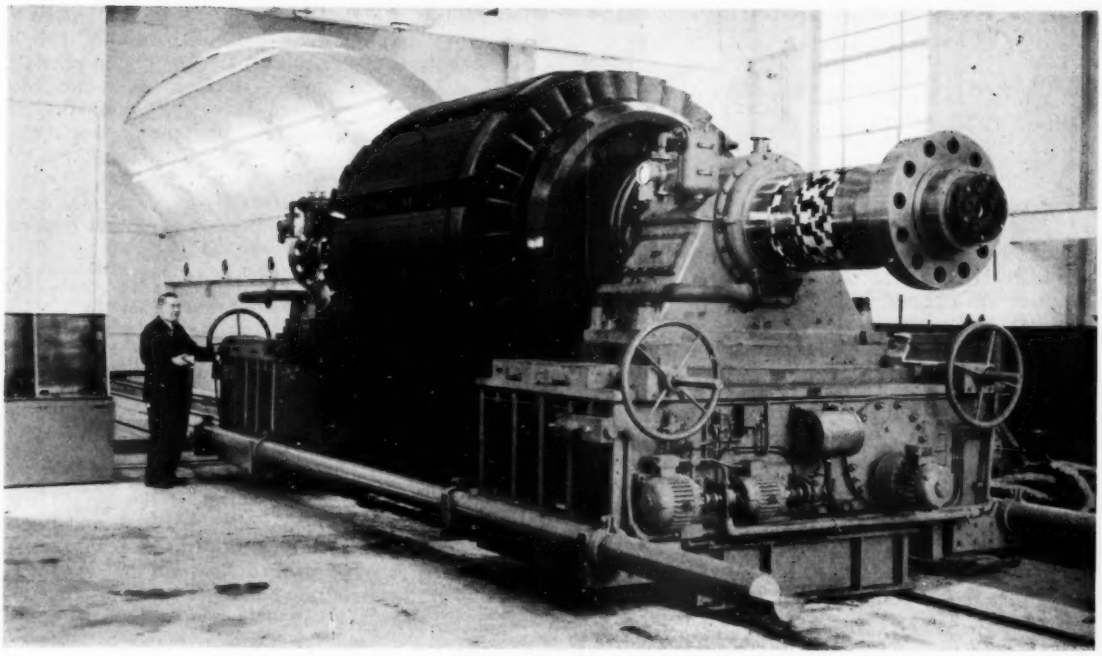
While the main function of the equipment is to load loose materials piled, stacked or blasted free above ground level, it will dig effectively to 10 in. below ground level—a feature that increases its value for general utility work.

In normal use it loads its bucket and then reverses to the waiting truck or waggon to discharge, while the load is travelling overhead. However, the load may be held overhead in any position when necessary, and at such a time the operator has full visibility both in front and to the rear, with the load stably balanced whatever the terrain. Discharge is effected by a separate automatic tripping action at the end of the rearward movement. The discharge is thus positive and controlled, and the same movement has the additional advantage in that the bucket delivery edge can extend over a vehicle which has sides higher than the actual ground clearance of the bucket edge.

An angle dozer blade is available as an attachment. This makes a very effective economy where the loader is being used only part time in its normal capacity. When equipped with angle dozer blade on the dual-purpose frame it is claimed to form a robust tool, comparable in efficiency to equipment made solely for that purpose. It also has the advantage of an exceptionally high limit for dozing, which permits out-of-the-way operations to be undertaken.

Hydro-Electric Generators for Spain

The first of two of the largest high-speed salient-pole generators ever manufactured in Great Britain was recently completed at the Rugby works of the British Thomson-Houston Co. Ltd. for the Artias hydro-electric power station, Spain. These 36,000 kVA machines, which are for horizontal operation, are each to be driven at 600 r.p.m by an overhung



Rotor of the B.T.H. 36,000 kVA generator ready for overspeed test

Pelton wheel at each end, and are designed for a runaway speed of 1100 r.p.m.

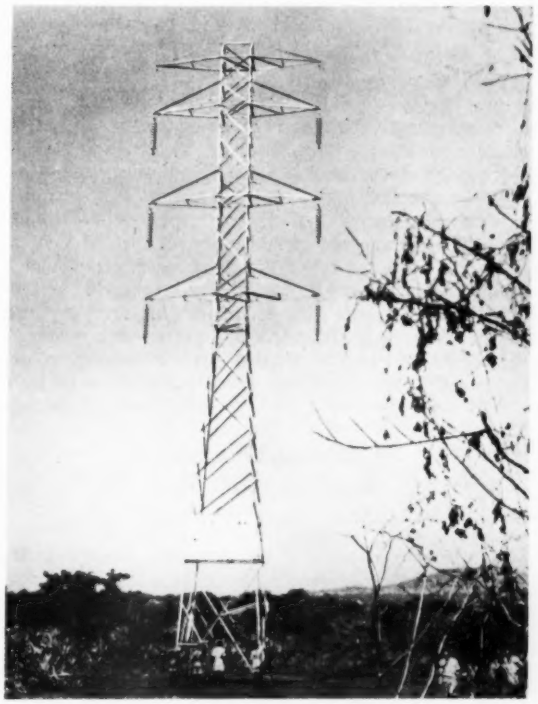
Important features of the generators are their exceptionally high efficiency and high flywheel effect, the former being guaranteed under heavy penalty. An efficiency figure of over 98·2 per cent. was obtained on tests, this representing a comfortable margin over the guarantee figure.

The station is situated in the Pyrenees at a height of more than 3,700 ft. above sea level, and consequently, due to transport difficulties, an interesting mechanical design of rotor was adopted. A stub shaft is bolted at each end of a prestressed hollow forging which forms the centre hub to which each pole is secured by four dovetails. All poles and both stub shafts will be removed before the machines are shipped to site, and even so the centre hub will be only just within the maximum transport weight of 40 tons.

First 132 kV Line in East Africa

Work is already well advanced on the first 132 kV overhead line in East Africa now being constructed for the Uganda Electricity Board to transmit power from the Owen Falls hydro-electric station. This line is some 120 miles long in two sections, one running westwards from Owen Falls to Kampala, the commercial centre of Uganda, and the other eastwards from Owen Falls to Tororo, a growing township near the Kenya border.

The country which the line traverses is undulating, with much dense forest and large areas of papyrus swamp. During the rainy season the roads are frequently in poor condition and considerable difficulty is experienced in transporting the materials necessary for building the line and sometimes these have to be manhandled appreciable distances by native porters. A typical tower is shown in the accompanying illustration. British Insulated Callender's Construction Co. Ltd. secured the contract.



One of the Owen Falls towers under construction

Abstracts from the World Technical Press

Italian Electrical Industry

A detailed account of the activities of ANIDEL (Associazione Nazionale Imprese Produttrici e Distributrici di Energia Elettrica), the Italian Branch of the International Union of Producers and Distributors of Electrical Energy, is given in the minutes of meetings held in Rome on June 1, 1953.

The report of the ANIDEL Council to its General Assembly presents an exhaustive survey of the Italian Electrical Industry for the year 1952. Following a short note on the organisation of the Association, the survey is divided into various sections such as: general situation, production, hydrologic characteristics, classes of consumer, progress, future programmes, tariffs, and legislation.

Comprehensive statistics are given in 26 tables, followed by 21 plates of maps and graphs in colours which cover all aspects of production and distribution. Technical questions are dealt with in appendix 2, which contains the proceedings of the various Technical Committees of the Technological Board. The close contact between technological and scientifical research is demonstrated by the work of Committees 9 and 10 (pp. 668-672), which attend to the coordination of relations with the electro-technical and physical laboratories, and the hydraulic laboratories respectively. Details are given of the work being undertaken by various hydraulic laboratories attached to Universities and High Technical Schools. (*L'Energia Elettrica*, Vol. XXX, No. 10, October 1953, p. 609, 74 pp., 21 ff.).

Size of Hydro-Electric Plants

A comparative survey is given of the size of hydro-electric plants in Italy, France, Switzerland, Spain, Norway, Sweden and U.S.A. The author first deals with the absolute and relative distribution of installed capacity among plants of various potential ranges, and gives the average capacity per plant in M.V.A. as follows:—Italy 14·4; France 15·3; Switzerland 19·7; Spain 10·3; Norway 14·1; Sweden 17·8; U.S.A. 23·9. The characteristics of some of the major plants in the countries instanced are given in a separate table. The survey concludes with a review of the degree of utilisation of the plants. (*Quaderni di Studi e Notizie*, Vol. 9, No. 144, p. 233, 6 pp., 10 tables).

Mexican Projects

In western Mexico the Tepalcatepec River project —power and irrigation—is scheduled for completion next year, and in eastern Mexico the similar but much larger Papaloapan River development, known as the TVA of Mexico, is now 90 per cent. complete. Under construction since 1947, the two principal dams of the latter project, Presidente Aleman Dam and the smaller Santo Domingo Dam, will be altered to reduce estimates from $45 to $26 million. At Santo Domingo, the dam site has been changed and its storage capacity will be smaller, this reduction being compensated by increased storage at Presidente Aleman Dam, just downstream. This scheme will provide a number of new cities, farming areas and industries for people from the drought-stricken La Laguna region of north Mexico. The Tepalcatepec Development, in the State of Jalisco, comprises three dams: the Canhondo irrigation dam on the Cupatizio River, the Cobano hydro and irrigation dam on the Tepalcatepec itself, and the Piedras Blancas Dam, which also serves as a bridge. When finished, this project will irrigate 50,000 acres and generate 120,000 kW. (*Engineering News-Record*, Vol. 152, No. 1, Jan. 7, 1954, p. 47).

Chatou Hydraulics Laboratory

A full description is given of the French State Laboratory completed in 1947 as a joint venture of the Ministry of Public Works and Electricité de France for pursuing hydraulic research. The buildings and other installations are sited on the downstream tip of the Chatou Island, close to the western boundary of Paris between the Chatou Bridge and the barrage across the Chatou arm of the Seine. Fig. 1 shows the general plan of the buildings, and Fig. 2 the detailed plan of the administrative building and testing hall A. The ground floor of the two-storey administrative building houses the offices, drawing office and copying room, and the first floor the managerial offices, the library and a temporary canteen. The offices are connected with the main laboratory building by a lecture room capable of accommodating 120 people and equipped with a projector. It is flanked by two passages leading to the basement where there is a testing hall. The 8-m wide measuring channel in front of hall A will ultimately be extended as far as hall 3, with an aggregate length of 155 metres. Once completed, the three halls will form a single testing space obstructed by four supporting columns only.

Hall A is a reinforced concrete structure 40 × 18 and 8 metres high, with a very slightly vaulted roof, and covers an area of 680 sq. metres. Under floor level there are three 250 cu. m. water tanks. Two 2-ton travelling cranes are provided and excellent lighting is derived from a number of strong projectors which can be moved and adjusted according to requirements. A partition wall suspended to a travelling crane enables the hall to be divided into two sections. Curtains provide for darkening the hall when photographs require to be taken. Three centrifugal pumps

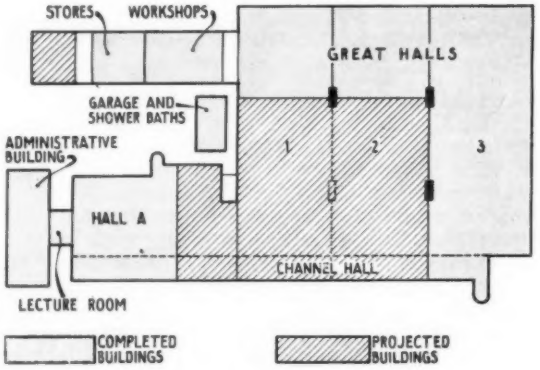


Fig. 1. General plan of the Chatou Laboratory

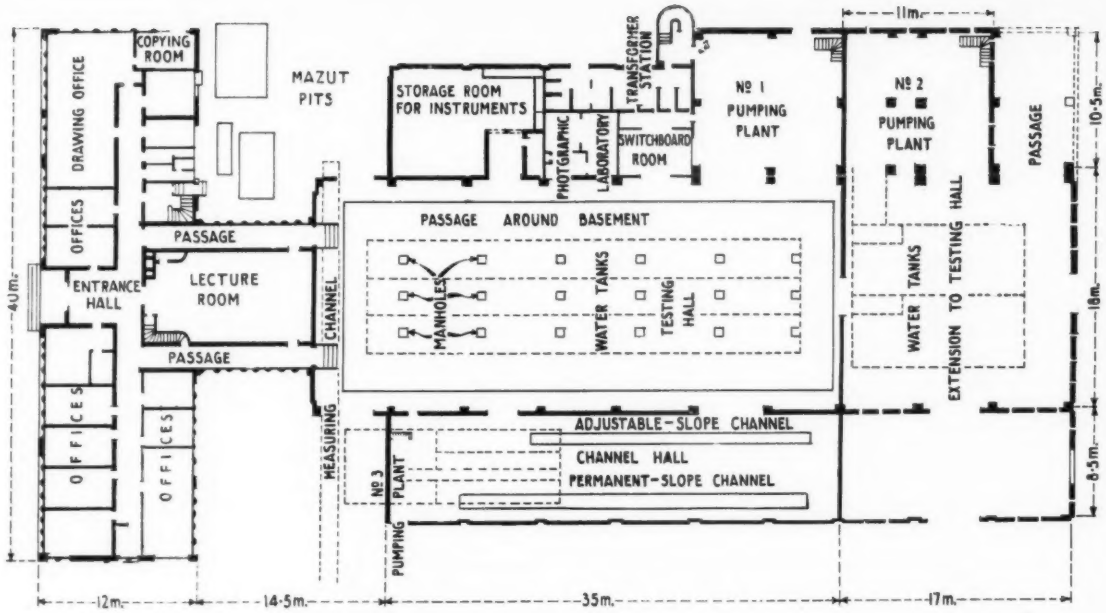


Fig. 2. Plan of administrative building and testing hall A

in the basement of No. 1 pumping plant, with capacities of 300, 150 and 75 lit. per sec. respectively, convey the water from the tanks into smaller vessels under constant pressure. These small vessels have an aggregate content of 40 cu. m. and can be operated separately so as to provide for three independent water circuits for the models.

The channel hall houses two troughs, one with a permanent slope and the other with one that can be adjusted up to 9 per cent.; the latter, fully enclosed by glass and equipped with an inlet of appropriate design and closing sluices, is 20 m. in length by 0·7 m. in height, and its width can be varied between 0·2 and 1·0 m. The permanent-slope channel is 1·0 × 1·0 m. in cross section, by 30 m. in length and has glass side walls. It receives the required amount of water by means of a special inlet nozzle. Measurement of water quantities is facilitated by a water conduit and an outlet gutter. The supply of water in a closed circuit is ensured by two pumps with a capacity of 200 and 250 lit. per sec. respectively, and 400 mm. dia. pressure conduits fitted with Venturi meters. The water tanks underneath the fixed floors of No. 1 and 2 halls have an aggregate capacity of 3,500 cu. m.; under the floor of No. 3 hall and along the gable walls, there are two tanks 300 and 500 cu. m. respectively. A pipe network, partly completed, connects the tanks of the three halls. Mounted on the four supporting columns, there are small concrete tanks operating under a constant lift of 14 m.

In hall A are installed a transformer station, a storage compartment for instruments with provision for repairs, and a fully-equipped photographic and cinematographic laboratory. A separate building houses the workshops for general requirements, fine mechanics, carpenter's work, welding and painting, as well as a storage room. In addition, there is a material dump and a sand-screening plant.

Besides investigations on behalf of Electricité de France, the scope of work of the Chatou Laboratory also extends to research connected with port installations. The Laboratory operates in close co-operation with all other hydraulics research institutions in France and abroad, as well as with the Technical Committee of the Société Hydrotechnique de France, and the International Association for Hydraulic Research, special emphasis being placed on work connected with hydroelectric power. The staff consists of two chief engineers, 20 engineers, 26 technicians, and 14 clerks, as well as of a permanent labour force of 44 for the workshops, masonry work, storage rooms and dumps (*Technische Rundschau*, Vol. 45, No. 49, Dec. 4, 1953, pp. 11 and 13, 7 ff.)

Radioactive Snow Gauges

The U.S. Corps of Engineers has developed a telemetering system that uses radioactive snow gauges to bring into a control centre daily reports of the water content of remote snow packs. The gauge consists of a heavy lead tube planted in vertical position flush with the ground. In the lower end of the tube, two units (40 millicuries) of cobalt 60 have sufficient strength to penetrate and measure the snow depth equivalent of 55 in. of water; this cobalt retains half life after 5·3 years so that decay corrections within a winter season are negligible. Cobalt 60 provides radiation of steady intensity (essentially monochromatic)—a condition necessary for satisfactory operation. A lead cap on the tube is used to reduce radiation below danger level while the gauge is transported and placed in the ground. The lead tube directs a stream of gamma rays from the cobalt, so that at 15 ft. above ground the principal energy is contained within 1·5 ft. circle. Within this area, a Geiger-Mueller tube is suspended from a steel-pipe gallows frame;

this structure is 18 ft. high by 20 ft. between uprights to minimise interference from natural settlement of snow over the gauge, and consists of 5 ft. threaded sections which can be easily carried by pack train. The Geiger-Mueller tube is used as radiation detector because it has short "dead time" or lapse between responses, requires low operating voltage, and is stable and rugged enough for outdoor use. Output of the tube is cabled to a telecoder which converts pulse signals into a modulated signal of 8·5 and 10 kilocycles. The first unit of this system has been installed in the Kings River watershed on the west slope of California's Sierra Nevada; runoff from this area will be controlled by the Pine Flat Dam, soon to go into operation. In this instance, signals from the telecoder are fed to a data transmitter which broadcasts a signal to Pine Flat receiving station via a repeater station set up at an altitude of 10,050 ft. on Spanish Mountain. Signals are picked up and translated into counts per minute; based on calibrations made at snow gauge sites; these indications will be converted directly into inches of water. (*Engineering News-Record*, Vol. 151, No. 26, Dec. 24, 1953, p. 24, 3 ff.)

Reorganisation of U.S. Bureau of Reclamation

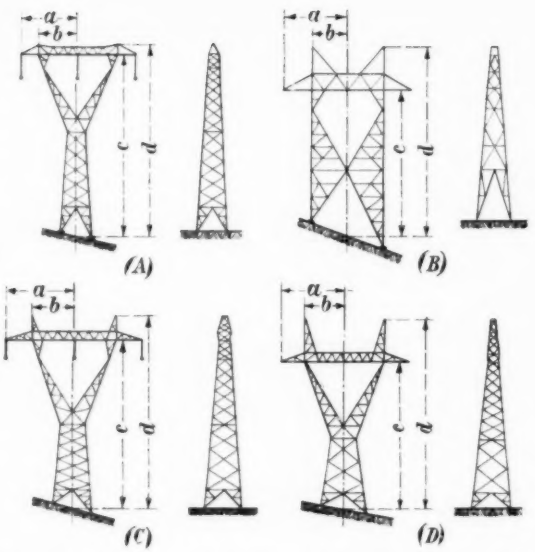
The main feature of this reorganisation scheme is the transfer of the key point from Washington to Denver, and the shifting of operational control from the central office to field echelons. Operations started at the end of October, 1953, the immediate goal being to centre the Bureau top-level technical work in Denver, where the major engineering functions are already located. Reorganisation, which provides for decentralisation of contract procedure, is to be carried out in three phases over a three-month period. (*Engineering News-Record*, Vol. 151, No. 19, Nov. 5, 1953, pp. 21/22.)

Calculating Overhead Transmission Lines

In this short article, the author discusses the range of applicability of the parabolic hypothesis and of Blondel's chart to the mechanical calculation of overhead lines, and assesses, for a horizontal span, the error resulting from the substitution of the equivalent parabola for the catenary. The instance of a slightly inclined span of moderate length is then examined and reduced to the case of the horizontal span, that is to say the inclined span a' is taken as equal to its horizontal projection a. Cases of steeper spans must be considered within the hyperbolical hypothesis, if substantially greater accuracy is aimed at. (M. Rousseau, Professor at Liège University, *Bulletin Scientifique A.I.M.*, Vol. 66, No. 10, October, 1953, p. 767, 7 pp., 1 f.)

Lienz-Pelos Transmission Line

A description is given of the new Austro-Italian transmission line inaugurated at Lienz on September 27, 1953, connecting the Austrian grid with the SADE system (Società Adriatica di Elettricita). This line, intended and designed as a link in the future 220 kV European interconnection system, now operates at 130 kV; its Italian section leads from Pelos, the head plant of the Piave Development, to the Cima Vallona Pass on the Austro-Italian border, where it connects



Transmission towers on Lienz-Pelos line. A and B are towers in the Austrian section and C and D in the Italian section

with the Austrian section ending at the Lienz transformer sub-station. The main characteristics are as follow:—

Length of line	20·953 km.
Elevation above sea level: maximum	2,450 m.
minimum	760 m.
Highest difference in level in a single span	222 m.
Highest level-span ratio	222 : 380 = 0·58.
Span: longest	530 m.
shortest	98 m.
mean	285 m.

The plotting of the line proved particularly difficult in the Austrian section which crosses the Lienz Dolomites at an elevation of 1,878 m. in the Kofel Pass and in the Carnic Alps at an elevation of 2,273 m. It was possible, however, to by-pass almost all avalanche zones in the former pass while only two danger spots in the latter had to be provided with protective works. With regard to the dimensioning of the steel towers and of their foundations, as well as of the conductors and guard wires, the whole line was divided into four zones in accordance with the loads expected to occur from wind and ice. Throughout the whole length of the line there are three steel-aluminium conductors laid in a horizontal plane, with two guard wires of galvanised steel. The setting up of a substation at the northern end of the Austrian section was made necessary by the connection with the Austrian grid. (*L'Energia Elettrica*, Vol. XXX, No. 10, Oct. 1953, p. 681, 11 pp., 12 ff.)

CLASSIFIED ADVERTISEMENTS

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